# SCADAPack E DNP3 Technical Reference

Documentation

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# I DNP3 Technical

Schneider Electric

Documentation

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|---|---|
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|---|---|
| Inside Australia | 1300 369 233 |
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## 2 Safety Information

Read these instructions carefully, and look at the equipment to become familiar with the device before trying to install, operate, or maintain it. The following special messages may appear throughout this documentation or on the equipment to warn of potential hazards or to call attention to information that clarifies or simplifies a procedure.

| | |
|---|---|
| | The addition of this symbol to a Danger or Warning safety label indicates that an electrical hazard exists, which will result in personal injury if the instructions are not followed. |
| | This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death. |

| ⚠DANGER |
| --- |
| **DANGER** indicates an imminently hazardous situation which, if not avoided, **will result in** death or serious injury. |

| ⚠WARNING |
| --- |
| **WARNING** indicates a potentially hazardous situation which, if not avoided, **can result** in death or serious injury. |

| ⚠CAUTION |
| --- |
| **CAUTION** indicates a potentially hazardous situation which, if not avoided, **can result** in minor or moderate. |

| CAUTION |
| --- |
| **CAUTION** used without the safety alert symbol, indicates a potentially hazardous situation which, if not avoided, **can result in** equipment damage.. |

## PLEASE NOTE

Electrical equipment should be installed, operated, serviced, and maintained only by qualified personnel. No responsibility is assumed by Schneider Electric for any consequences arising out of the use of this material.

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## BEFORE YOU BEGIN

Do not use this product on machinery lacking effective point-of-operation guarding. Lack of effective point-of-operation guarding on a machine can result in serious injury to the operator of that machine.

| ⚠CAUTION |
| --- |
| **EQUIPMENT OPERATION HAZARD** |
| • Verify that all installation and set up procedures have been completed.<br>• Before operational tests are performed, remove all blocks or other temporary holding means used for shipment from all component devices. |

| |
|---|
| • Remove tools, meters, and debris from equipment. |
| **Failure to follow these instructions can result in injury or equipment damage.** |

Follow all start-up tests recommended in the equipment documentation. Store all equipment documentation for future references.

Software testing must be done in both simulated and real environments.

Verify that the completed system is free from all short circuits and grounds, except those grounds installed according to local regulations (according to the National Electrical Code in the U.S.A, for instance). If high-potential voltage testing is necessary, follow recommendations in equipment documentation to prevent accidental equipment damage.

Before energizing equipment:

- Remove tools, meters, and debris from equipment.
- Close the equipment enclosure door.
- Remove ground from incoming power lines.
- Perform all start-up tests recommended by the manufacturer.

### OPERATION AND ADJUSTMENTS

The following precautions are from the NEMA Standards Publication ICS 7.1-1995 (English version prevails):

- Regardless of the care exercised in the design and manufacture of equipment or in the selection and ratings of components, there are hazards that can be encountered if such equipment is improperly operated.
- It is sometimes possible to misadjust the equipment and thus produce unsatisfactory or unsafe operation. Always use the manufacturer's instructions as a guide for functional adjustments. Personnel who have access to these adjustments should be familiar with the equipment manufacturer's instructions and the machinery used with the electrical equipment.
- Only those operational adjustments actually required by the operator should be accessible to the operator. Access to other controls should be restricted to prevent unauthorized changes in operating characteristics.

# 3 Preface

The purpose of this document is to describe the DNP3 Slave implementation for the SCADAPack E RTU. It covers interaction of the SCADAPack E with a DNP3 master station, DNP3 networking, DNP3 - TCP/IP communication, and brief descriptions of the DNP3 protocol.

This document does not describe SCADAPack E communication as a DNP3 Master (see the

*SCADAPack E Data Concentrator Technical Reference Manual*).

## Target Audience

- Systems Engineers
- Commissioning Engineers
- Maintenance Technicians

## References

- SCADAPack E Configurator User Manual
- SCADAPack E Reference Manuals
- ICS Triplex ISaGRAF Manuals
- SCADAPack E Hardware Manuals

## Assumed Knowledge

Exposure to the DNP3 protocol is recommended. It is also recommended that the readers familiarize themselves with the Schneider Electric SCADAPack E Configurator tool required to configure the SCADAPack E RTUs.

# 4 Introduction

## What is DNP3?

DNP3 *(Distributed Network Protocol)* is an industry standard SCADA communications protocol. It originated in the Electricity Industry in North America and was based on drafts of the IEC870-5 SCADA protocol standards (now known as IEC60870-5). DNP3 is now in widespread use in many industries across the world and is managed by the DNP User Group.

DNP3 describes standards for SCADA protocol facilities such as data requests, polling, controls, and report by exception (RBE). Master-slave and Peer-to-Peer communication architectures are supported by DNP3.

Inter-operability is one of the key aspects of DNP3. It is enforced by way of minimum implementation subsets to which vendors need to adhere. Currently, the DNP3 standard is supplemented by Subset Definitions document describing 4 minimum subset levels. In addition, a vendor's DNP3 implementation needs to be provided with a *Device Profile* document describing information required by the DNP User Group, including details of the implementation of one of the four minimum subset levels, and other protocol information. The Device Profile is now required in machine readable XML format.

The DNP3 protocol also caters for expansion & evolution of the standard without detracting from the strengths of inter-operability that it promotes. This is achieved by an object-oriented approach to the data. Data objects can be added to the DNP3 Standard without affecting the way that devices inter-operate.

The DNP3 User Group has published definitions for the operation of DNP3 protocol over TCP/IP LAN and WAN networks.

## What does the SCADAPack E RTU Provide when using the DNP3 Protocol?

The SCADAPack E RTU supports DNP3 to Subset Level 4 slave implementation with a range of additional features from the DNP3 standard.

In summary the SCADAPack E RTU provides the following facilities for use of DNP3:

- SCADA data configuration
- Simultaneous DNP3 operation on Multiple Ports
- Networking DNP3 frames
- Peer-to-Peer communication
- DNP3 over TCP/IP LAN & WAN networks

# 5 DNP3 Protocol Structure and Configuration

The Standard DNP3 protocol structure is:

OBJECT LIBRARY
APPLICATION LAYER
TRANSPORT FUNCTIONS
DATALINK LAYER
PHYSICAL LAYER

A data link layer (DLL) packet is referred to as a *FRAME.*

| | | |
|---|---|---|
| SCADAPack E RTU Data link layer frames | Transmitted Frame Size: | Adjustable 292 bytes |
| | Max. Transmitted: SCADAPack E Default Frame Transmit size: | 249 bytes |
| | Max. Receive Frame Size: | 292 bytes |

An application layer packet is referred to as a *FRAGMENT.*
DNP3 Application layer fragment size: Max. 2048 bytes

| | | |
|---|---|---|
| SCADAPack E Application layer fragments | Transmitted Fragment Size: | Adjustable 2048 bytes |
| | Max. Transmitted: SCADAPack E Default Frame Transmit size: | 2048 bytes |
| | Max. Received Fragment size: | 2048 bytes |

The job of the *Data link layer* is to:

- Transmit DNP3 data frames on the physical medium.
- Receive and frame DNP3 data from the physical medium.

The job of the *Transport function* is to:

- sub-divide a transmitted application fragment into DLL frames
- re-assemble received DLL frames into an application fragment

The SCADAPack E RTUs add a transparent networking facility to DNP3. With minimal overhead and no affect on inter-operability, this allows these devices to forward DNP3 frames to other DNP3 nodes, transparent to the protocol.

The SCADAPack E RTU DNP3 structure is as follows:

OBJECT LIBRARY
APPLICATION LAYER
TRANSPORT FUNCTIONS
*NETWORK FUNCTIONS*
DATALINK LAYER

PHYSICAL LAYER

The job of the RTU's DNP3 network functions is to:

- pass DLL frames for this DNP Node address to the Transport layer
- determine if the destination node for received DLL frames appears in the network routing table to be passed back to the DLL layer for transmission on a DNP physical channel
- discard DLL frames not for this node & not to be forwarded to another node

The job of the Application layer is to:

- process received fragments for this DNP node. It determines the type of operation requested (e.g. Read, Operate, etc.) and decodes references to objects for processing in the object library.
- build and manage outgoing data such as peer requests and unsolicited responses.

The *Object library* determines which objects are processed, and how they are processed for this DNP device. (e.g., Binary Input, 32-bit Analog Input, Files, Floating point Analog Output, Binary Change Event, 16-bit Analog Change Event, or 32-bit Counter).

Configuration for the DNP3 communication parameters is described in the following sections:

- ***DNP3 Data Link Layer Configurations*** 12
- ***DNP3 Application Layer Configurations*** 14

## Related Topics

STATUS ASSOCIATIONS 78

ASSOCIATION STATES 82

## 5.1 DNP3 Data Link Layer Configurations

The lowest level of DNP3 communication on the physical channel is DNP data-link communication. This level of communication operates independently on each RTU serial port channel configured for DNP3. Therefore each DNP3 communication channel on the SCADAPack E RTU can be independently configured for a certain mode of operation.

Data link confirmation can be requested by DNP3 nodes as a means of synchronizing & guaranteeing the delivery of frames. The Data Link Confirm Mode parameter, referred to as **DL Confirm Mode** in SCADAPack E Configurator *DNP3 Comms* page determines how frames that are transmitted from this node should be confirmed by the receiving node. A screen capture of the DL Confirm field from SCADAPack E Configurator is presented below.

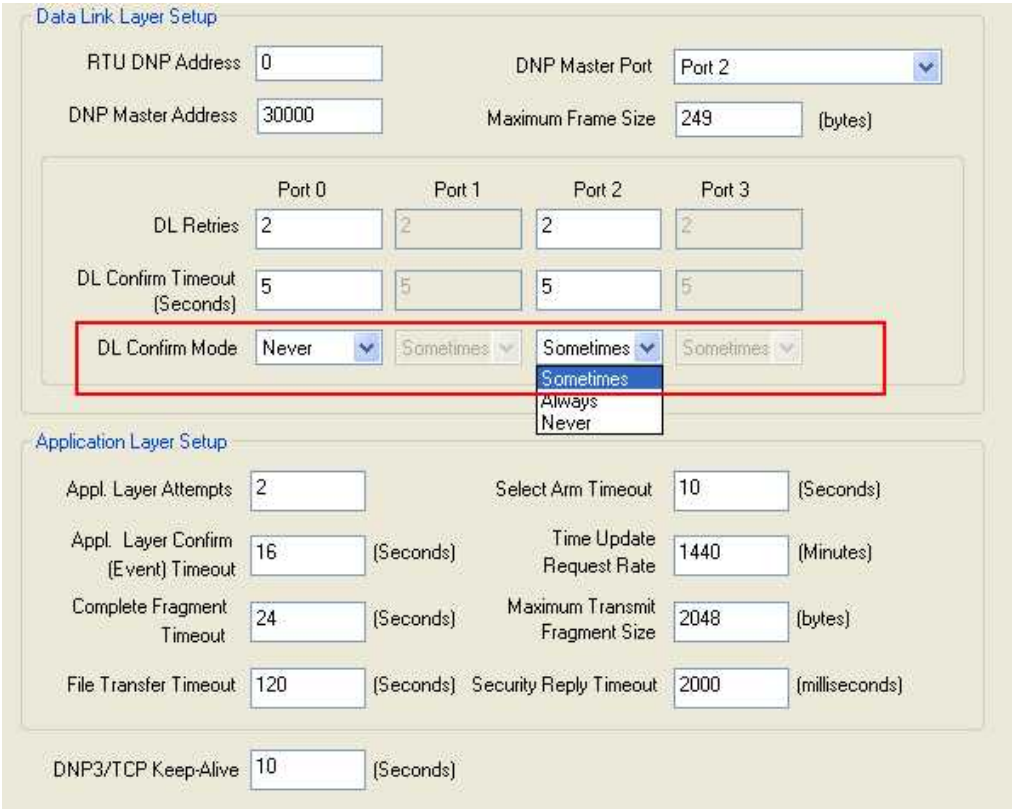


**Figure 5.1: SCADAPack E Configurator DL Confirm Mode**

The options are defined as follows:

| | |
|---|---|
| NEVER | Never set data-link confirm required for a transmitted frame. This mode should be used where single frame messages are the only messages transmitted, or where transmission is on a highly robust medium (e.g. local serial connection between two devices), improving communication throughput |
| ALWAYS | Always require a data link confirm to a transmitted frame. This mode should be used on unreliable links to improve communication delivery. |
| SOMETIMES | Only require a data link confirm for frames where multiple frames are transmitted to a node. This mode is applicable on devices using a range of message sizes, from |

single to multi-frame messages, on potentially unreliable links. The use of this mode improves data delivery by being able to re-transmit individual frames rather than entire multi-framed messages.

Where a data link confirmation is requested on a transmitted frame (ALWAYS or SOMETIMES modes) the RTU waits a certain time interval for the requested confirmation. The maximum length of this time interval is determined by a *DL Confirm Timeout* parameter accessible from the *DNP3 Comms* page of SCADAPack E Configurator as illustrated below. The DL Confirm Timeout period is independently adjustable on each RTU serial port and can take a value from 0 to 65535 seconds.

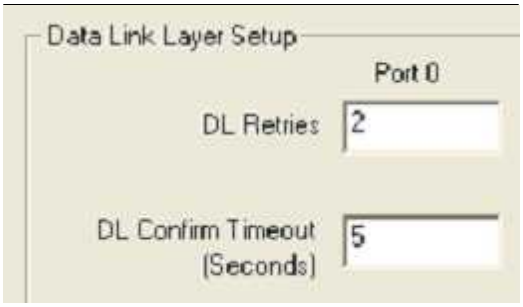


**Figure 5.2: SCADAPack E Configurator Data Link Confirm Timeout Field**

If a data link confirmation is requested but not received within the timeout period specified, the data-link frame is resent, up to the number of retries configured by the *DL Retries* parameter. If the number of retries is exceeded, then the frame is undeliverable and the application layer generating the message is notified. The DL Retries parameter may have a value between 0 and 255.

## 5.2 DNP3 Application Layer Configurations

The highest level of DNP3 communication having user adjustable parameters is the application layer. The settings at this layer are global to the RTU and dictate the behavior of data generated by this RTU. ***Figure 5.3*** 14 below presents the Application Layer setup parameters available on the *DNP Comms* page of SCADAPack E Configurator.

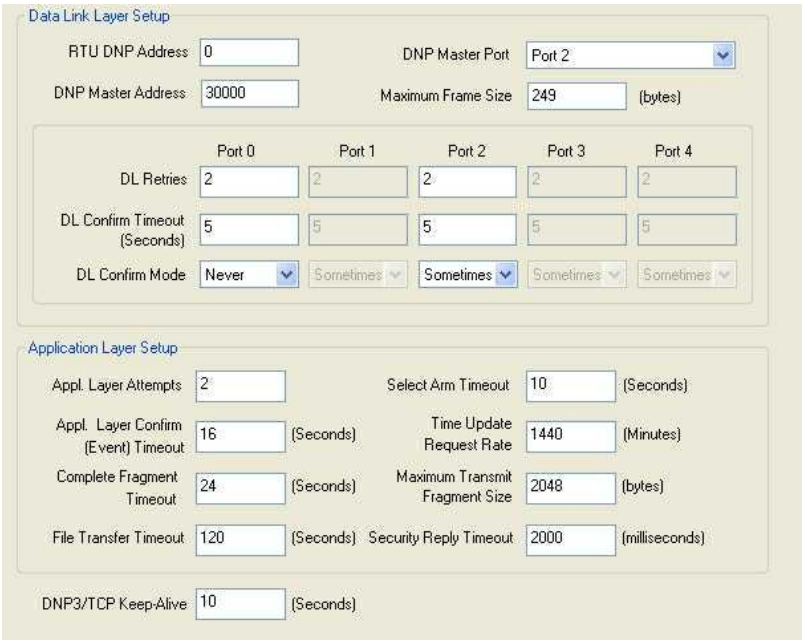


**Figure 5.3: SCADAPack E Configurator Application Layer Setup**

The **Appl Layer Attempts** parameter determines the number of times the RTU will attempt to send and resend a request if a matching response is not received. This parameter sets the total number of attempts between 1 and 255 (if this value is set to zero, the RTU will still perform one attempt). After each transmission, the RTU waits for the *Complete Fragment Timeout* period before attempting to resend. This parameter may be set between 0 and 65535 seconds.

These parameters are only applicable to *Request* messages generated from this RTU and not response messages, for example, an unsolicited response containing events (see *Min Unsol Event TX Delay* and *Appl Layer Confirm (Event) Timeout* for more information).

Another example of an application layer request generated by an RTU is the peer-to-peer communication function blocks within ISaGRAF. In this particular case, a timeout can be applied individually to each communication request (DT parameter). Where DT is zero (0) the *Complete Fragment Timeout* is used as the default timeout value. Where a communication function block timeout is non-zero, the communication function block value is used. (For more information see the *ISaGRAF Technical* and the *SCADAPack E Target 5 Technical Reference* Manuals*)*.

The **Appl Layer Confirm (Event) Timeout** parameter sets the time for an SCADAPack E RTU to wait for a DNP3 Application Layer Confirmation message from the master after the RTU has transmitted event data (either in a poll response or unsolicited response). The minimum value of this parameter is automatically calculated by the RTU. You can set a value greater than the minimum, and reading this parameter after a Warm Restart will indicate its current value. This parameter may be set up to 65535 seconds. If an Application Layer Confirmation is not received from the master, then the greater of this value and the *Min Unsol TX Delay* parameter is used to delay the RTU transmitting new unsolicited event

data to the master (including retries of unsolicited event data).

If data link confirmations are used to acknowledge successful transmission of frames to the master (see *Data Link Confirm Mode* above), the minimum application layer confirm timeout is calculated by the RTU so that all data link retries can be completed. The minimum value is calculated as follows:

Min.Timeout = ((*Data Link Retries* + 1) * *Data Link Confirm Timeout*) + 1,

where *Data Link Retries* and *Data Link Confirm Timeout are* those specified for the Master Port (or port communicating with the master RTU). The *Appl Layer Confirm (Event)* timer is restarted when a data link confirmation is received from the master. This allows the transmission of a complete fragment without the application layer timing out.

Other Application Layer parameters include the *Complete Fragment Timeout, Select Arm Timeout, Time Update Request Rate, and Maximum Transmit Fragment Size*.

The **Complete Fragment Timeout (Seconds)** parameter sets the time, in seconds, that the RTU will wait for an Application Layer Response before re-attempting the transmission (or discarding) of an Application Layer Request.

A typical example of an Application Layer Request generated by the RTU is the peer-to-peer communication function blocks within ISaGRAF. For these function blocks, the Complete Fragment Timeout is used as the default timeout, which may be over-ridden by the function block. For more information refer to the *ISaGRAF Technical* and the *SCADAPack E Target 5 Technical Reference* Manuals.

The **File Transfer Timeout (Seconds)** parameter extends the RTU's application layer timing when waiting for fragments dealing with File Transfer operations. File transfer transactions typically take longer than other DNP3 communication transactions. The default value for this field is 120 seconds.

The **Select Arm Timeout (Seconds)** parameter sets the timeout, in seconds, before which an Operate command needs to be received after the Select command is received for a two-phase Select/Operate DNP3 Control. If an Operate command (matching a recently received Select command) is not received within this period then the Control operation is aborted. A ***select arm timeout*** status is returned in a DNP3 Control Relay Output Block (operate) response to the sender, in this case. If an Operate command (matching a recently received Select command) is received within this period then the Control operation is performed.

When receiving two-phase Select/Operate DNP3 controls, an Operate command needs to be received within this period after the Select command is received. If a DNP3 Operate command (matching a recently received Select command) is not received within this period then the control operation is aborted and a *select arm timeout* status (1) is returned in a Control Relay Output Block (operate) response to the sender. If an Operate command (matching a recently received Select command) is received within this period then the control operation is performed.

The **Time Update Request (Minutes)** Internal Indications (IIN) returned with each DNP3 communications response. The next outgoing RTU response (due to a request from the master to the RTU, or due to an unsolicited response from the RTU to the master) will contain this request indication. A value of zero (0) in this field disables time update requests.

The **Maximum Transmit Fragment Size** parameter sets the size of the application layer fragment transmitted by the RTU. The allowable range for this field is 1 to 2048. The default value for this field is 2048 bytes.

| To be compatible with existing SCADAPack E controllers, the default is 2048 bytes. |
|---|

**DNP3-TCP Keep Alive** parameter is implemented as described by the DNP User Group's "*Transporting*

*DNP3 over Local and Wide Area Networks*" standard. It is a configurable Keep-Alive timer is used for each active DNP3 - TCP socket connection. This configuration parameter specifies how often a DNP3 Link Status test message is sent across active TCP sockets for the purpose of verifying an active TCP link. This timer may be set to "0" to de-activate the DNP-TCP Keep-Alive timer.

The **Security Reply Timeout** parameter is the time after which a device will stop waiting for a reply. It is settable in hundreds of milliseconds.

# 6 SCADA Master DNP3 Interaction


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## 6.1 SCADA Master Data Requests and Events

### SCADA Master Data Requests

A DNP3 SCADA master may request static (current value) data from an RTU in one of two ways:

1. Read request for data objects with specific point index ranges
2. Class 0 object as part of a read request

The specific data enquiry requires no RTU configuration as the DNP3 master knows what it is going to request. The RTU returns a response for requests to data specified in a start/stop DNP3 point index range for particular DNP3 object/variations (this is a minimum requirement of the Level 3 DNP3 subset).

### Request including a Class 0 Object

A general read request that includes a *"Class 0"* object causes the RTU to respond with data according to its configuration. Class 0 is typically included in a request along with Class 1,2 and 3 event data; this type of request is known as an Integrity Poll. The data that is returned by the RTU in response to a Class 0 object in a read request is a configured subset of the RTU's *STATIC* data. See Section ***SCADA Master Data Configuration*** 18.

### Events

Events are generated by the SCADAPack E RTU based on the configuration of points in the RTU database.

Three different event classes are defined *"Class 1, Class 2, and Class 3 events"*. Each point in the SCADA table can be selected as not being an event (class 0 static or Local point), or an event being in one of the three event classes. Event class 1 is nominally the highest priority, and class 3 is nominally the lowest. The DNP3 SCADA master can enforce event priorities, e.g., request Class 1 events more often than Class 2 or 3 events.

DNP3 Masters may request events buffered in the RTU a single class at a time, or in combinations of classes. The RTU may also perform unsolicited reporting of events.

Each point configured with an event (i.e., having an event class of 1,2, or 3) has a corresponding static data value (class 0). Events are generated from changes in the static data point. Points configured with "Class 0 static" in the CLASS field report data in response to a SCADA poll, but events are not generated.

## 6.2 SCADA Master Data Configuration

Configuration of the RTU for transmitting DNP3 data to the DNP3 SCADA master is organized through the RTU point database configuration.

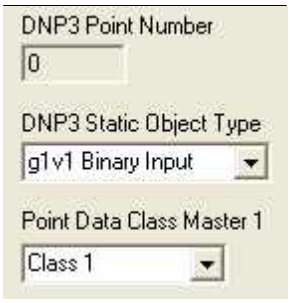



**Figure 7.1: RTU Point Database Configuration Dialog**

Using SCADAPack E Configurator, point records are configured with the following fields:

The *DNP3 Static Object Type* field describes the object type to be reported in a response to a Class 0 poll request. (See SCADA Objects)
The *Point Data Class* field assigns the DNP point(s) as “LOCAL” (not reported to the SCADA Master), static data only (Class 0), or as an event class (Class 1,2, or 3). Events may be configured as "Unsolicited" or "Buffered". The *Point Data Class* field can be set to Local, Class 0 (Static), Class 1, Class 2 or Class 3 as illustrated below:

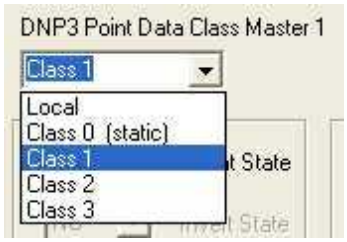



**Figure 7.2: Point Data Class Field**

This field is accessible when configuring a DNP point in the RTU database as illustrated in the figure below.

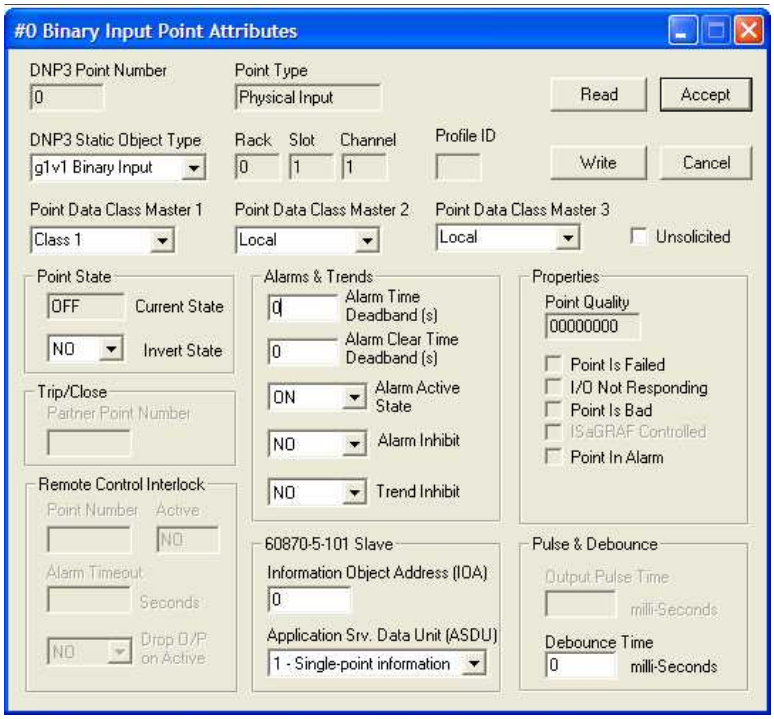



**Figure 7.3: Point Static Object and Data Class Attributes**

Analog and Counter points types have a *Deviation* attribute that is used when a point is set with an event class as illustrated in . The Deviation field is used in detection of "change-of-value" for generating events. See Section ***Event Generation*** 24.

ANALOG Deviation

COUNTER Deviation

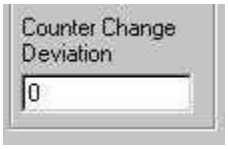
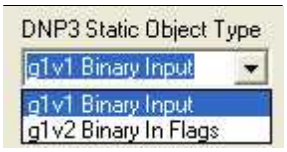



**Figure 7.4: Analog and Counter Point Deviation Attributes**

The following objects can be configured in the RTU Point Configuration *DNP Static Object Type* fields for the various point types, and are returned to the DNP SCADA master in a response to a Class 0 poll request (unless the Point Data Class is set to LOCAL as described above).

### 6.2.1 Binary Points

BINARY INPUT Points




BINARY OUTPUT Points

BINARY DERIVED Points

**Figure 7.5: BINARY Point Types**

One of these configurations is set for each binary input, binary output and derived binary point, and determines the type of DNP3 object returned to represent the status of the binary point.

## DNP3 Group 1 Variation 1 – Binary Input

Use this object to return the state of binary inputs and derived points. The minimum transmitted data size for this object is 8 bits. Eight consecutive binary input objects are the same data length as a single binary input object. It is beneficial to group binary objects together in consecutive addresses to improve transmission efficiency. If the point quality for a particular point is not indicated as "good quality" the a DNP3 Group 1 Variation 2 object will be automatically reported by the RTU for that point (this is a DNP3 protocol requirement).

## DNP3 Group 1 Variation 2 – Binary Input Status

Use this object to return the status of a binary point where the DNP3 master can process point quality flags, for example, on-line, off-line or downstream device communication lost.

## DNP3 Group 10 Variation 2 – Binary Output Status

Use this object to return the status of a binary output or derived point. Some DNP3 SCADA masters may require this object to be defined and returned in an integrity poll response in order for the output point to be controlled. Other DNP SCADA masters may not require this object to be returned to control a DNP point. In both cases it can be used to notify the DNP SCADA master if the point state is modified elsewhere (e.g. internal state validation and point quality).

### 6.2.2 Analog Points

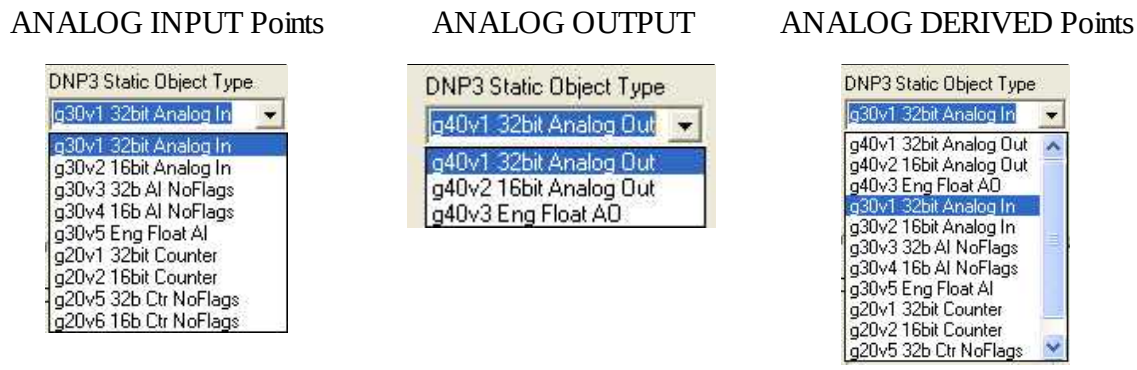



**Figure 7.6: ANALOG Point Types**

One of these configurations is set for each analog input, analog output and derived analog point, and determines the type of DNP3 object returned to represent the value and status of the analog point.

## DNP3 Group 30 Variation 1 – 32-Bit Analog Input

Use this object to return a 32-bit integer analog value from an analog input or derived point with a range $-2^{31}$ to $+2^{31}-1$ where the DNP3 master can process additional point quality flags, for example, over-range or calibration check.

## DNP3 Group 30 Variation 2 – 16-Bit Analog Input

Use this object to return a 16-bit integer analog value from I/O or data points with a range –32768 to +32767 where the DNP3 master can process additional point quality flags, for example, over-range or calibration check.

## DNP3 Group 30 Variation 3 – 32-Bit Analog Input No Flag

Use this object to return a 32-bit integer analog value with a range $-2^{31}$ to $+2^{31}-1$. This object does not include quality flags however If Group 30 Variation 3 object type is configured but a point does not have "good quality", it is automatically changed to report Group 30 Variation 1 (this is a DNP3 protocol requirement).

## DNP3 Group 30 Variation 4 – 16-Bit Analog Input No Flag

Use this object to return a 16-bit integer analog value from an analog input or derived point with a range –32768 to +32767. This object does not include quality flags, however If Group 30 Variation 4 object type is configured but a point does not have "good quality", it is automatically changed to report Group 30 Variation 2 (this is a DNP3 protocol requirement).

## DNP3 Group 30 Variation 5 – Short Floating Point Analog Input

Use this object to return the value and status of analog input or derived points, in 32-bit IEEE floating point format.

## DNP3 Group 40 Variation 1 – 32-Bit Analog Output Status

This object returns the value and status of a 32-bit analog output or derived point. Some DNP3 SCADA masters may require this object to be defined in the RTU SCADA table for it to be controlled. Some

DNP3 SCADA masters may require this object to be defined and returned in an integrity poll response in order for the output point to be controlled. Other DNP SCADA masters may not require this object to be returned to control a DNP point. In both cases it can be used to notify the DNP SCADA master if the point value is modified elsewhere (e.g. internal state validation and point quality).

## DNP3 Group 40 Variation 2 – 16-Bit Analog Output Status

This object returns the value and status of a 16-bit analog output or derived point. Some DNP3 SCADA masters may require this object to be defined and returned in an integrity poll response in order for the output point to be controlled. Other DNP SCADA masters may not require this object to be returned to control a DNP point. In both cases it can be used to notify the DNP SCADA master if the point value is modified elsewhere (e.g. internal state validation and point quality).

## DNP3 Group 40 Variation 3 – Short Floating Point Analog Output Status

Use this object to return the value and status of floating point control data. Some DNP3 SCADA masters may require this object to be defined and returned in an integrity poll response in order for the output point to be controlled. Other DNP SCADA masters may not require this object to be returned to control a DNP point. In both cases it can be used to notify the DNP SCADA master if the point value is modified elsewhere (e.g. internal state validation and point quality).

### 6.2.3 Counter Points & Octet String Objects

## Counter Points

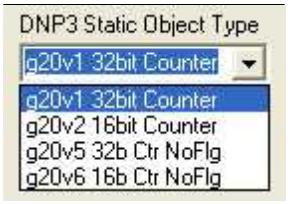



**Figure 7.7: COUNTER Point Types**

One of these configurations is set for each physical counter input and derived analog point used as a counter. It determines the type of DNP3 object returned to represent the value and status of the counter point.

## DNP3 Group 20 Variation 1 – 32-Bit Counter

Use this object to return data for a counter with 32-bit resolution in the range 0 to $+2^{32}$-1 where the DNP3 master can process additional point quality such as counter offline. The point may be a physical counter, or a derived analog point that is used as a counter point.

## DNP3 Group 20 Variation 2 – 16-Bit Counter

Use this object to return data for a counter with 16-bit resolution in the range 0 to 65535 where the DNP master can process additional point quality such as counter offline. The point may be a physical counter, or a derived analog point that is used as a counter point.

## DNP3 Group 20 Variation 5 – 32-Bit Counter No Flag

Use this object to return data for a counter with 32-bit resolution in the range 0 to $+2^{32}$-1. This object does not include quality flags however If Group 20 Variation 5 object type is configured but a point does not have "good quality", it is automatically changed to report Group 20 Variation 1 (this is a DNP3 protocol requirement).

## DNP3 Group 20 Variation 6 – 16-Bit Counter No Flag

Use this object to return data for a counter with 16-bit resolution in the range 0 to 65535.This object does not include quality flags however If Group 20 Variation 6 object type is configured but a point does not have "good quality", it is automatically changed to report Group 20 Variation 2 (this is a DNP3 protocol requirement).

## Octet String Objects

The SCADAPack E RTU String System points are provided for setting and viewing text configurations. The following objects are accessible, but not necessarily used for data reporting to the SCADA Master.

1. **DNP3 Object - Group 110 – Octet String**
   The Variation of this object represents the length of the string. Use this object to set or read the value of RTU system string points.

## 6.3 Event Generation

Events are generated by the SCADAPack E RTU based on changes in static data points. The RTU will scan for changes on points configured in the SCADA point tables with event classes (i.e. Class 1,2, or 3).

Timestamps are applied to events generated by the RTU, representing the RTU's real time clock at the time of occurrence. I.e. The timestamp is in either UTC or Standard Time format depending upon how the clock is set. For more information see *SCADAPack E Operational Reference Manual*. Daylight savings time does not affect event timestamps.

A change in state of a binary point will result in the generation of an event of the configured class for that point, timestamped at the time of occurrence of the change.

A change in value of an analog, floating point analog, or counter point by a value greater than or equal to the point's configured deviation will result in the generation of an event. The event will be of the configured class for that point, timestamped at the time of occurrence of the change.

Analog "change-of-value" (for integer and floating point analogs and counter points) is calculated based on the absolute difference between the last transmitted and current value. The calculation is as follows:

change-of-value **=** ABS (last transmitted event value **–** current value)

If this value is greater or equal to the analog deviation value, an event is generated i.e.

**if** (change-of-value **>=** deviation) **then** generate a point event

Generated events are stored in the SCADAPack E Smart RTU memory and are retained through a power cycle (Run mode startup). See the *Startup Modes* section of the SCADAPack E Smart RTU Hardware Manual for further information on Startup Modes.

## 6.4 Event Buffering

Analog, Float and Counter events have a further option depending on the capabilities of the DNP3 master. Analog event buffering may be operated in one of two ways: *Single* mode or *Multiple* mode.

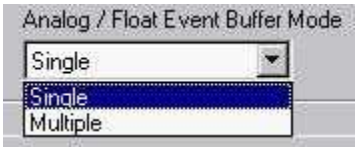



**Figure 7.8: Analog Event Buffer Dialog**

In *Single* mode, only the recent instance of an event for a particular DNP analog point will be recorded in the event buffer. Some older DNP3 masters cannot process more than a single analog event (the recent), so in these cases use *Single Mode*.

Only new analog or counter events entering the event list are counted by the RTU when determining unsolicited operation based on minimum number of class events. (See next section). Analog and counter events replacing existing events on the event lists are not counted.

In *Multiple* mode (default), every analog and counter event is stored.

If the DNP3 Master station does not support decoding of multiple analog and counter events, then it is more efficient for the RTU to be operated in *Single* mode. The RTU can then store and transmit more events for other points than it could if many events were stored for a single analog point.

The number of events stored varies between RTU types (see following table).

| RTU Type | No. Binary Events | No. Counter Events | No. Integer Analog Events | No. Float Analog Events |
|---|---|---|---|---|
| SCADAPack ES and SCADAPack ER | Max. 40000 Events (of every type combined) | | | |
| SCADAPack 300E | Max. 20000 Events (of every type combined) | | | |

SCADAPack E RTUs provide a "**Unsol. Max. Event Storage**" analog system point at 50362. The value of this point defines an upper limit on the size of the event pool, up to the maximum values described above. An RTU Restart is required for a change in this value to take effect. It is possible for stored non-volatile events to be lost if this value is reduced and the RTU restarted.

The SCADAPack E RTU provides "Event Data Threshold" status and "Event Data Lost" status messages on these event lists. "Event Data Threshold" (RTU status code 1030) is generated when the number of events on any of the lists exceeds 80% event list capacity.

Handling of new event data once an event list is filled depends upon the setting of an RTU system point.

**Binary System Point**

| DNP Point Index | Description | Comment |
|---|---|---|
| 50304 | Stop Data Storage if Full | ON = Stop storing events<br>OFF = Discard oldest events (default) |

This system point also affects the storage of Trend Data by the Sampler. See the *SCADAPack E Trend Sampler Technical Reference* manual**.**

"Event Data Lost" (RTU status code 1031) is generated when the number of events on any of the lists exceeds the list capacity. In this case, the oldest event (of the same type as the new event) is discarded. The SCADA Master is also notified through the DNP3 "*Event Buffer Overflow*" IIN flag in the next DNP3 response.

- SCADAPack E ISaGRAF supports the ***GEN_EVT*** and ***GENMSEVT*** function blocks which provides a mechanism to force generation of DNP3 events on appropriately configured DNP3 points. The value included in the forced DNP3 event will be the current point database value of the point in question. These function blocks also have *Time* (gen_evt) or *msTime* (genmsevt) input parameters that optionally allows a timestamp to be included in the forced DNP3 event. See the *SCADAPack E ISaGRAF Function Blocks Reference* and *SCADAPack E Target 5 Function Block Reference* manuals for more information on the *GEN_EVT* and *GENMSEVT* function blocks.

## 6.5 Event Count System Points

Firmware versions 7.5-1 and later supports a range of 16-bit analog system points to represent the current number of buffered DNP3 events for each event type, for each DNP3 Master. This range of points is not configurable and cannot be returned in a class poll. The range of points can be read with a DNP3 qualifier 01 read (e.g. ClearSCADA Level 3 scan), by using the SCADAPack E Configurator or from an ISaGRAF application. See the following table for further details:

**Table 7.1: Event Count System Points**

| System Point Description | DNP3 Analog System Point No. (16-bit) |
|---|---|
| Binary Input Event Count – Master 1 | 58000 |
| Counter Input Event Count – Master 1 | 58001 |
| Analog Input Event Count – Master 1 | 58002 |
| Float Input Event Count – Master 1 | 58003 |
| Binary Output Event Count – Master 1 | 58004 |
| Analog Output Event Count – Master 1 | 58005 |
| Float Output Event Count – Master 1 | 58006 |
| Binary Output Command Event Count – Master 1 | 58007 |
| Analog Output Command Event Count – Master 1 | 58008 |
| Float Output Command Event Count – Master 1 | 58009 |
| | |
| Binary Event Count – Master 2 | 58015 |
| Counter Event Count – Master 2 | 58016 |
| Analog Event Count – Master 2 | 58017 |
| Float Event Count – Master 2 | 58018 |
| Binary Output Event Count – Master 2 | 58019 |
| Analog Output Event Count – Master 2 | 58020 |
| Float Output Event Count – Master 2 | 58021 |
| Binary Output Command Event Count – Master 2 | 58022 |
| Analog Output Command Event Count – Master 2 | 58023 |
| Float Output Command Event Count – Master 2 | 58024 |
| | |
| Binary Event Count – Master 3 | 58030 |
| Counter Event Count – Master 3 | 58031 |
| Analog Event Count – Master 3 | 58032 |
| Float Event Count – Master 3 | 58033 |

| | |
|---|---|
| Binary Output Event Count – Master 3 | 58034 |
| Analog Output Event Count – Master 3 | 58035 |
| Float Output Event Count – Master 3 | 58036 |
| Binary Output Command Event Count – Master 3 | 58037 |
| Analog Output Command Event Count – Master 3 | 58038 |
| Float Output Command Event Count – Master 3 | 58039 |

## 6.6 Event Transmission

Each event generated by the SCADAPack E RTU is buffered in the internal RTU event list. The RTU can send an event transmission to the SCADA in one of several ways:

1. In response to a DNP3 SCADA master request for a quantity of events for one, every, or a combination of event classes.
2. An unsolicited transmission of events may occur if the number of events on the list exceeds a preset maximum for that event class.
3. An unsolicited transmission of events may occur if an *UNSOLICITED EVENT* occurs on an event class enabled by the master for unsolicited reporting.

A minimum number of events for each event class can be set individually from the DNP3 Events page of the SCADAPack E Configurator as illustrated in ***Figure 7.9*** 29 below. Once the number of events generated exceeds this minimum amount for any of the event classes, the RTU will send an unsolicited transmission of every event in the enabled event classes. (See Section ***Event Settings*** 31).

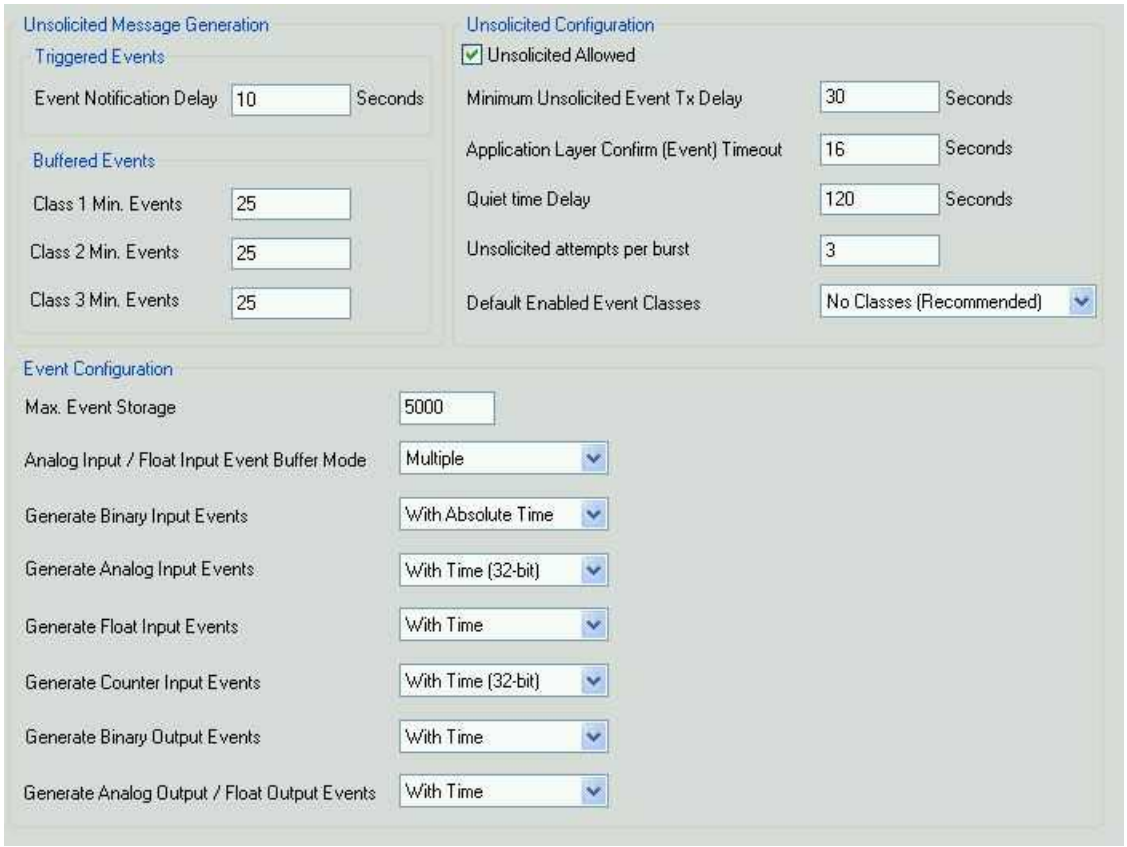



**Figure 7.9: SCADAPack E Configuration of Buffered Events**

The *Class X Min Events* parameters refer to event classes and are independent of the event buffer list sizes (see table below). Events removed from overflowing event lists are not decremented from the count of class events, i.e. the *Min Events* count is a minimum number of new events generated.

A slightly different behavior occurs if the RTU is in *Single* ANALOG EVENT BUFFER MODE, where only analog or counter events on a new point entering the list count toward this minimum when determining

unsolicited operation. Analog and counter events replacing existing events on the event lists are not counted.

RTU data points configured as events have one of two event attributes.

- The occurrence of an event with a *BUFFERED EVENT* attribute (i.e. not selected for Unsolicited reporting) is added to the internal event list. No direct action is taken by the RTU after the event is added to the list unless the new event causes an event list size to exceed the transmission limit for an enabled event class.
- The occurrence of an event with a *UNSOLICITED* attribute is also added to the internal event list, but causes the RTU to generate an unsolicited transmission containing the events currently on the event list, for the enabled event classes.

Each of the eight enabled Analog Alarm Limits, Point Quality change events and Point Current Value/ State Deviation events can be individually assigned to generate either “Buffered” or "Unsolicited" DNP event types.

This feature has advantages for RTU’s using dial-up or on “pay-per-byte” links where the user wants to minimize the unsolicited reporting and hence communications costs. For example, an RTU may be configured to Buffer all Current Value Deviation events, but to send Triggered DNP events if a certain Alarm limit is transgressed.

The screen capture in ***Figure 7.10*** 30 below illustrates some of the Analog Point attributes that can be configured to generate a triggered event. Triggered events are enabled with the fields containing a check mark.

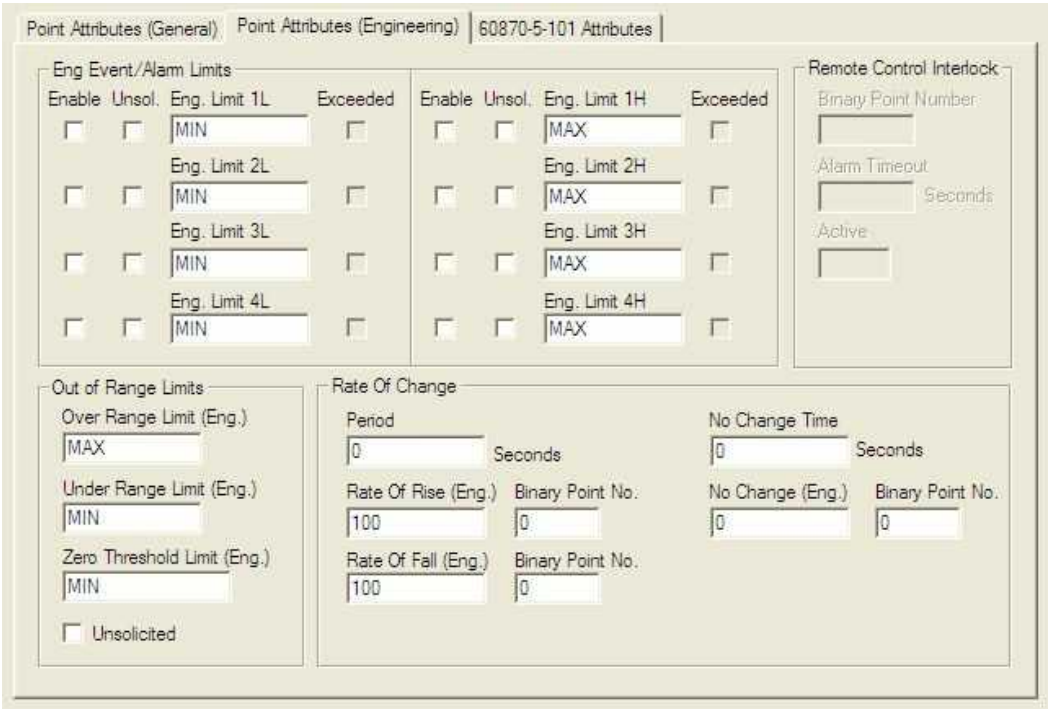



**Figure 7.10: Analog Event Triggering Enabled**

For more information about these fields, refer to the *SCADAPack E Configuration Technical Reference* manual.

## 6.7 Event Settings

Unsolicited transactions from the RTU to the DNP SCADA master require the following configurations:

**Figure 7.11: SCADAPack E Configurator DNP Master Configuration**

This dialog can be accessed from the *DNP Comms* page of SCADAPack E Configurator. These fields set the DNP node address of the DNP SCADA master, and the RTU port that the master can be found on (one of: DIAG, PORT0, PORT1, PORT2, FSK).

| |
|---|
| The default DNP Master Addr is 30000 and default *DNP Master Port* is Port 1. |

If the port selected as the “DNP Master Port” is not configured for “DNP3” protocol on the RTU, then the configuration will be automatically modified to be the first port found that is configured with “DNP3” protocol. If the user re-reads the configuration page in the SCADAPack E Configurator, it will report the selected “DNP Master Port” if it was automatically modified.

Unsolicited Event Transmission can be controlled by the DNP SCADA master issuing “*Disable Unsolicited Messages”* & “*Enable Unsolicited Messages”* commands. These allow the DNP SCADA master to selectively enable & disable CLASSES of events from being reported by the RTU. If disabled from sending unsolicited events, the RTU continues to buffer the events.

The default start-up state of an RTU’s Unsolicited Event Classes is configurable as illustrated in the screen capture in ***Figure 7.12*** 31 taken off the *DNP Events* page of SCADAPack E Configurator.

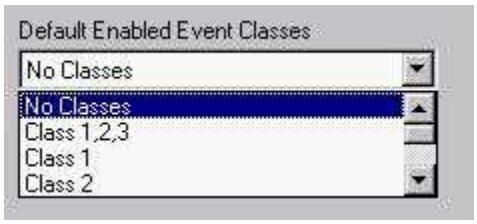



**Figure 7.12: Default Enabled Event Classes**

The SCADAPack E RTU firmware supports an “Unsolicited Allowed” control to satisfy recently revised DNP User Group DNP3 operational requirements. When Unsolicited responses are off, the RTU will not support any unsolicited operation, and will reject the “ENABLE/DISABLE UNSOLICITED RESPONSES” DNP3 function codes. This function is also configured on the DNP Events page of SCADAPack E Configurator as illustrated below.

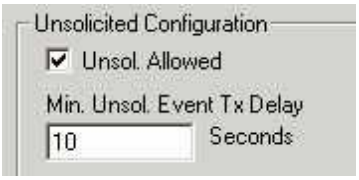



**Figure 7.13: Unsolicited Response Configuration**

When unsolicited operation is enabled on the RTU, it is the responsibility of the DNP3 Master to enable the event classes in the RTU following an RTU restart. The *Class* settings are provided for backward compatibility with older masters not automatically enabling RTU event classes. When supporting the *Unsolicited Allowed* mode, it is recommended that *Class* settings should not be used with a DNP3 Level 2 compliant master station.

Unsolicited responses will not be generated by the RTU unless it has a configuration loaded into it. Writing configuration values in SCADAPack E Configurator is insufficient for this purpose. A configuration needs to be loaded using the restart config command or writing a configuration via SCADAPack E Configurator.

### 6.7.1 Unsolicited Response transmission timing

The SCADAPack E Configurator DNP3 Events page in ***Figure 7.14*** 33 presents the SCADAPack E Configuration of the Unsolicited Response timing on the SCADAPack E RTU.

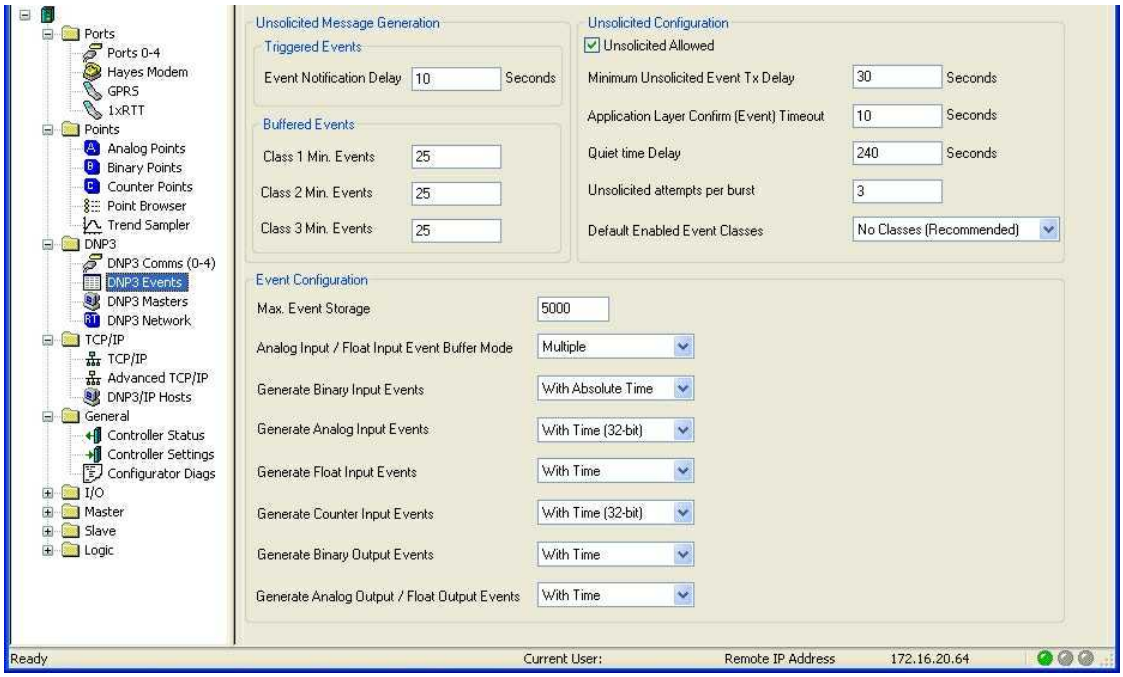



**Figure 7.14: Unsolicited Response Timing Configuration**

The *Event Notification Delay* field allows the RTU to continue collecting events for the configured period AFTER the occurrence of a *TRIGGER EVENT* but before transmission of the event list to the DNP SCADA master. This can be useful where a trigger event is followed by consequential events. This allows the trigger event and consequential events to be reported together in the same DNP3 fragment. The value of this period may be between 0 and 65535 seconds.

There are 5 parameters that affect the timing of subsequent Unsolicited Response transmissions.

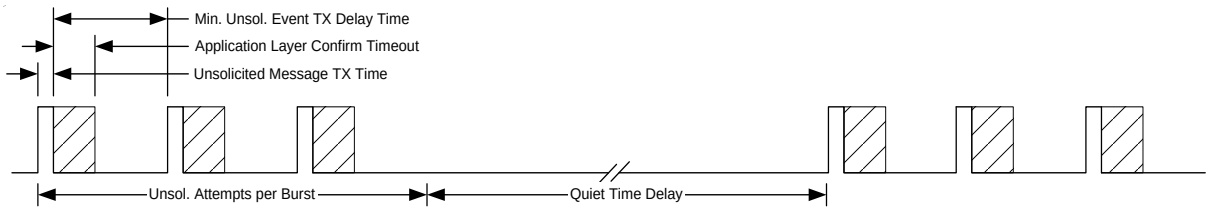

Min. Unsol. Event TX Delay Time
Application Layer Confirm Timeout
Unsolicited Message TX Time
Unsol. Attempts per Burst
Quiet Time Delay

**Figure 7.15: Unsolicited Response Timing Parameters**

The *Min. Unsol Event Tx Delay* field stops the RTU from transmitting unsolicited events too frequently e. g., a new trigger event occurring outside the event notification delay will have to wait this period of time from the transmission of the previous event, before it will be transmitted. The value of this period may be between 0 and 65535 seconds.

In conjunction with the APPL LAYER CONFIRM (Event) TIMEOUT, this time also sets the *re-*

*transmission* rate for events if the RTU does not receive an application confirm from the DNP3 SCADA master to its event transmission.

The *Quiet Time Delay* parameter is the “offline” value for the *Min. Unsol. Event Tx Delay* time. This value is applied when the number of timed-out Unsolicited Responses reaches the *Unsol. Attempts per burst* count. These parameters allow the RTU to implement “burst-mode” where the RTU retries several times, waits for an extended time period, and then begins another burst of Unsolicited retries. This behavior is repeated indefinitely until an Application Layer confirmation is received. The benefit of using this scheme is that an RTU does not give up trying to notify the Master of a change, but the RTU pauses for extended period to allow time for “data storms” to clear. See ***Figure 7.15*** 33.

## 6.8 Event Objects

The objects reported by the RTU when communicating with the DNP3 SCADA master are configurable for each type of event. A range of objects is provided allowing a choice of suitable data type and choice of timestamp for each of the event types. The DNP Events page of SCADAPack E Configurator presents each of the event object types.

### 6.8.1 Binary and Counter Event Objects

## Binary Input Event Objects

One of the following event object types is configured for Generate Binary Input Events selection on the SCADAPack E Configurator DNP3 Events page.

## Generate Binary Input Events - No Time

Use this selection to generate DNP3 Group 2 Variation 1 binary input event objects when timestamps aren't required or the DNP3 SCADA master does not support timestamp binary events.

## Generate Binary Input Events - With Absolute Time

Use this selection to generate DNP3 Group 2 Variation 2 binary input event objects when the DNP3 SCADA master does support timestamp binary events, but does not support Relative Time objects (see SCADA Master's DNP3 Device Profile document).

## Generate Binary Input Events - With Relative Time

Use this selection to generate DNP3 Group 2 Variation 3 binary input events when the DNP3 SCADA master supports Relative Time timestamps and DNP3 Group 51 Variation 1 and Variation 2 CTO objects (see SCADA Master DNP3 Device Profile document). Where multiple RTU binary events tend to occur in close succession and need to be transmitted together, this is a more transmission efficient object than DNP3 Group 2 Variation 2.

## Binary Output Event Objects

One of the following event object types is configured for Generate Binary Output Events selection on the SCADAPack E Configurator DNP3 Events page.

## Generate Binary Output Events - No Time

Use this selection to generate DNP3 Group 11 Variation 1 binary output event objects when timestamps aren't required or the DNP3 SCADA master does not support timestamp binary events. If the DNP3 SCADA master does not support binary output event objects, set each binary output or binary derived point configuration to Local or Class 0 only (i.e. not configured as Class 1,2 or 3 event classes to the output points).

## Generate Binary Output Events - With Time

Use this selection to generate DNP3 Group 11 Variation 2 binary output event objects when the DNP3 SCADA master does support binary output events with timestamp (see SCADA Master's DNP3 Device Profile document).

## Generate Counter Input Events - No Time

Use this selection for counter events when the DNP3 SCADA master does not support or does not require timestamp counter events.

For firmware versions prior to 7.80 only, select "No Time (16-bit)" events if the DNP3 static object configuration for counters is 16-bit. If any points are configured for 32-bit DNP3 static counter objects, select "No Time (32-bit)".

For firmware versions 7.80 and later, the RTU automatically determines 16-bit or 32-bit event size for each counter point, based on its configured DNP3 static object data size. Select either "No Time (16-bit)" or "No Time (32-bit)".

- 32-bit counter events with no time are sent as DNP3 Group 22 Variation 1 objects.
- 16-bit counter events with no time are sent as DNP3 Group 22 Variation 2 objects.

## Generate Counter Input Events - With Time

Use this selection for counter events when the DNP3 SCADA master does support timestamp counter events.

For firmware versions prior to 7.80 only, select "With Time (16-bit)" events if the DNP3 static object configuration for counter points is 16-bit. If any points are configured for 32-bit DNP3 static objects, select "With Time (32-bit)".

For firmware versions 7.80 and later, the RTU automatically determines 16-bit or 32-bit event size for each point, based on its configured DNP3 static object data size. Select either "With Time (16-bit)" or "With Time (32-bit)".

- 32-bit counter events with time are sent as DNP3 Group 32 Variation 5 objects.
- 16-bit counter events with time are sent as DNP3 Group 32 Variation 6 objects.

### 6.8.2 Analog Event Objects

#### Generate Analog Input Events - No Time

Use this selection for analog events when the DNP3 SCADA master does not support or does not require timestamp analog events.

For firmware versions prior to 7.80 only, select "No Time (16-bit)" events if the DNP3 static object configuration for integer analog points is 16-bit. If any points are configured for 32-bit DNP3 static objects, select "No Time (32-bit)".

For firmware versions 7.80 and later, the RTU automatically determines 16-bit or 32-bit event size for each point, based on its configured DNP3 static object data size. Select either "No Time (32-bit)" or "No Time (16-bit)".

- 32-bit events with no time are sent as DNP3 Group 32 Variation 1 objects.
- 16-bit events with no time are sent as DNP3 Group 32 Variation 2 objects.

#### Generate Analog Input Events - With Time

Use this selection for analog events when the DNP3 SCADA master does support timestamp analog events.

For firmware versions prior to 7.80 only, select "With Time (16-bit)" events if the DNP3 static object configuration for integer analog points is 16-bit. If any points are configured for 32-bit DNP3 static objects, select "With Time (32-bit)".

For firmware versions 7.80 and later, the RTU automatically determines 16-bit or 32-bit event size for each point, based on its configured DNP3 static object data size. Select either "With Time (16-bit)" or "With Time (32-bit)".

- 32-bit events with time are sent as DNP3 Group 32 Variation 3 objects.
- 16-bit events with time are sent as DNP3 Group 32 Variation 4 objects.

#### Generate Float Input Events - No Time

Use this selection for float events when the DNP3 SCADA master does not support timestamp float events. The RTU will report DNP3 Group 32 Variation 5 events for floating-point analog input and analog derived point types.

#### Generate Float Input Events - With Time

Use this selection for float events when the DNP3 SCADA master does support timestamp float events. The RTU will report DNP3 Group 32 Variation 7 events for floating-point analog input and analog derived point types.

#### Generate Analog Output / Float Output Events - No Time

Use this selection when the DNP3 SCADA master supports analog output event objects but does not support or require timestamp analog output events.

The RTU generates events compatible with the analog output point's or analog derived point's DNP3 Static Object Type.

- DNP3 Group 42 Variation 1 events for 32-bit analog output data
- DNP3 Group 42 Variation 2 events for 16-bit analog output data
- DNP3 Group 42 Variation 5 events for 32-bit Short Floating Point analog output data

## Generate Analog Output / Float Output Events - With Time

Use this selection when the DNP3 SCADA master supports analog output event objects with timestamp.

The RTU generates events compatible with the analog output point's or analog derived point's DNP3 Static Object Type.

- DNP3 Group 42 Variation 3 events for 32-bit analog output data
- DNP3 Group 42 Variation 4 events for 16-bit analog output data
- DNP3 Group 42 Variation 7 events for 32-bit Short Floating Point analog output data

## 6.9 Control Objects

A SCADA Master, or peer DNP3 node may control DNP points within the SCADAPack E RTU. Some Master stations may have different requirements with respect to knowledge of RTU output points. A Master station's requirement, or otherwise, for output status points to be returned in a Class 0 poll response is independent of the RTUs ability to accept a control request. The following data objects may be sent to an SCADAPack E RTU for control.

The RTU supports DNP3 controls using the following control methods:

DIRECT OPERATE
SELECT / OPERATE
DIRECT OPERATE NO ACKNOWLEDGE

See Section ***DNP3 Application Layer Configurations*** 14 for information on the "Select Arm Timeout" parameter that affects the operation of the RTU using the DNP3 SELECT / OPERATE controls.

Some restrictions apply to control of the RTU data. Physical RTU Inputs are read-only and cannot be controlled. An attempt to control a physical binary input or physical analog input point results in a returned control status *"Control not supported for this point" (4)*.

Physical RTU Outputs and RTU User points may only be controlled when an ISaGRAF application is not controlling the point, or if a Remote Interlock point is defined and is active. An attempt to control a binary output or analog output point while ISaGRAF is controlling the point and a Remote Interlock point is not present, or not active, results in a returned control status *"Automation Inhibit" (10)*.

An attempt to control a Physical RTU output or RTU User point that has its "*Point is Failed*' attribute set (e.g. open loop Physical AO) will return a control status *"Hardware Error" (6).*

Controlling a Physical RTU output or RTU User point that does not exist will result in a control status *"Control not supported for this point" (4).*

Control of user points (internal to the RTU) may be performed at any time, subject to same restrictions as physical output points, i.e. may not be controlled via DNP3 if an ISaGRAF application is controlling the point, unless a remote interlock point is present and active.

### 6.9.1 Remote Control Interlock

The purpose of control interlocks is to arbitrate control of physical output points and user RTU points (digital and analog) between an ISaGRAF user application, and remote DNP3 control requests.

The *Remote Control Interlock* attribute of a point associates a separate RTU binary point with a point to be controlled. Remote Control Interlock points can be associated with Physical Digital Output points, Physical Analog Output points, user Digital points and user Analog points. The remote control interlock point itself may be a Physical Digital Input point or a user Digital point. The *Remote Control Interlock* attribute for each physical or user output point is configured from the property dialog of the corresponding point as illustrated in ***Figure 7.17*** 41 below.

If the Remote Control Interlock point value is zero, then there will be no interlock on the controlled point. Where a DNP3 control request is received for a point without a defined control interlock point, and the point is not on an ISaGRAF output board, the point will be controlled successfully. Where a DNP3 control request is received for a point without a control interlock point, and the controlled point is on an ISaGRAF output board, the DNP3 control will be rejected as described in Section ***Control Objects*** 40.

Where an interlock point is specified, the *Remote Interlock Point* can be controlled externally via DNP3.

When the interlock point is inactive (OFF) and the controlled point is on an ISaGRAF Output Board, external DNP3 control requests for the physical output point will be rejected as described in Section ***Control Objects*** 40. Controls asserted through an ISaGRAF application Output Board control the physical output point. When the interlock point is active (ON), external DNP3 control of the physical output point is allowed, and controls through an ISaGRAF Output board will be ignored.

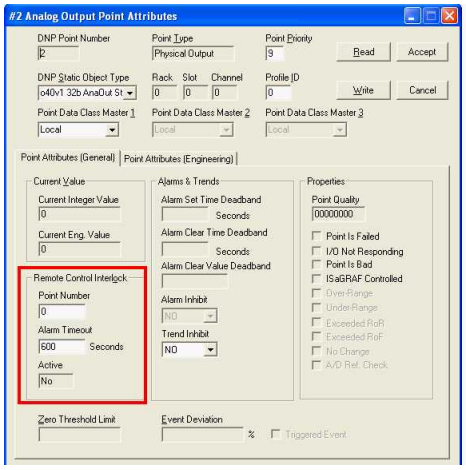



**Figure 7.17: Configuring Remote Control Interlock**

As the Interlock Point is writeable (Remote Control Interlock set to ON), either external DNP3 requests or an ISaGRAF application may control its state. ISaGRAF control of the interlock point requires a specific function block call, e.g. WR1BIN to Local_Data. If potentially controlled from an ISaGRAF application and DNP3, the interlock point should not be on an ISaGRAF output board.

**EXAMPLE:**
User defined analog point 1000 is controlled via a user application variable attached to an ISaGRAF Analog Output Board. Analog point 1000 has an associated Remote Control Interlock user digital point 1107. If digital point 1107 is activated, changes to the ISaGRAF variable will no longer control analog point 1000. Instead, DNP3 controls may be sent to analog point 1000 to change its value.

#### 6.9.1.1 Interlock Alarm Timeout

The Data Processor tracks the period of time that the Interlock binary point is in an Active (ON) state. Each time the Interlock point is set ON, the timer is restarted. If the timer period exceeds the value of the interlock “Alarm Timeout” attribute, the RTU generates a DNP3 event on the Interlock user binary point if the Interlock point has an event class configuration. The DNP binary change event generated will contain the current state of the Interlock point (ON). The DNP event will be regenerated every 10 mins thereafter, whilst the Interlock point is still active (ON). When the Interlock point is deactivated (OFF), the 10 min and “Interlock alarm timeout” timers are cleared and a change event will be generated for the Interlock point (with point state OFF). An “Alarm Timeout” value of zero indicates no interlock alarm timeout.

### 6.9.2 Binary Control Objects

ISaGRAF applications and remote-control interlocks may affect the control of RTU points. For more information see *SCADAPack E Data Processing Technical Reference* manual.

1. **DNP Object - Group 10 Variation 1 – Binary Output**
   Use this object with a DNP Write function code for controlling one, or multiple binary points. These points may be physical binary outputs, RTU user points, or system binary points.

   The minimum transmitted data size for this object is 8 bits. 8 consecutive binary output objects is the same data length as 1 single binary output object. Group binary objects together to improve transmission efficiency. The DNP Write function code does not return a control result. It is recommended that the result of this operation is check by another means such as feedback of the controlled state to a binary input point.

2. **DNP Object - Group 12 Variation 1 – Control Relay Output Block**
   Use this object (also known by the acronym CROB) with a Select/Operate pair of control messages, a Direct Operate, or a Direct Operate No Acknowledge DNP function code. The use of Direct Operate No Acknowledge is not recommended. This object may control physical binary outputs, RTU user points, or system binary points.

   The RTU supports CROB latch-on, latch-off and trip / close pulse controls. On-time / Off-time / Count fields are supported for pulse controls. See *SCADAPack E DNP3 Device Profile*. The operation of RTU points using a pulse control is further described in *SCADAPack E Configuration Technical Reference* manual.

The transmitted data size for each point using this object is 11 bytes. For multiple point operation in a single transaction, packet sizes can become large when using this object type. For large numbers of binary controls, use of Binary Output object 10 variation 1 is suggested if available in the master station. For object 1- variation 1, the returned DNP response does NOT return a control result for each point controlled.

## Trip Close Support

SCADAPack E RTUs support *TRIP/PULSE ON* and *CLOSE/PULSE ON* control codes in Control Relay Output Block (CROB) controls .

Extended support for TRIP CLOSE requests such that complementary control functions may be provided for a single index, i.e. a *TRIP/PULSE ON* request for a specific DNP index may map to a specific relay output, whereas a *CLOSE/PULSE ON* request for the same DNP index may map to another different relay output. This functionality requires configuration of the ***TRIP CLOSE PARTNER*** point attribute for a binary output point in the RTU's point database. Refer to the *SCADAPack E Configuration Technical Reference* manual for more information.

### 6.9.3 Analog Control Objects & Floating Point Analog Control Objects

## Analog Control Objects

ISaGRAF applications and remote-control interlocks may affect the control of RTU points.

For more information see the *SCADAPack E Data Processing Technical Reference* manual.

1. **DNP Object - Group 41 Variation 1 – 32-bit Analog Output Block**
   This object may be sent with a DNP Select/Operate pair of control messages, a Direct Operate, or a Direct Operate No Acknowledge DNP function code. The use of Direct Operate No Acknowledge is not recommended. Use this object when controlling internal RTU data requiring 32-bit signed integer values. This object may control physical analog outputs, RTU user points or analog system points.

| |
|---|
| For this object, the returned DNP response returns a control result for each point controlled. |

2. **DNP Object - Group 41 Variation 2 – 16-bit Analog Output Block**
   This object may be sent with a DNP Select/Operate pair of control messages, a Direct Operate, or a Direct Operate No Acknowledge DNP function code. The use of Direct Operate No Acknowledge is not recommended. Use this object when controlling internal or physical RTU data requiring 16-bit signed integer values. This object may control physical analog outputs, RTU user points, or analog system points.

| |
|---|
| For this object, the returned DNP response returns a control result for each point controlled. |

## Floating Point Analog Control Objects

ISaGRAF applications and remote-control interlocks may affect the control of RTU points.

For more information see the *SCADAPack E Data Processing Technical Reference* manual.

**DNP Object - Group 41 Variation 3 – Short Floating Point Analog Output Block**
This object may be sent with a DNP Select/Operate pair of control messages, a Direct Operate, or a Direct Operate No Acknowledge DNP function code. The use of Direct Operate No Acknowledge is not recommended. Use this object when controlling internal RTU data requiring 32-bit floating point (real) values.

| |
|---|
| For this object, the returned DNP response returns a control result for each point controlled. |

## 6.10 DNP3 IIN Internal Indication Flags

The DNP3 IIN Internal Indication flags are utilized by the RTU to indicate the status regarding operation of the RTU.

DNP3 IIN flags are returned by the RTU to the DNP3 Master Station in all response messages including Unsolicited Response messages.

**IIN Flags First Byte (RTU status)**
Bit #

**IIN1.0 All stations (broadcast) message received by RTU**
The RTU sets this IIN flag when it receives a broadcast message. This flag is cleared automatically after having been reported in a response fragment.

**IIN1.1 Class 1 event data available in RTU**
The RTU sets this IIN flag in a response when there is buffered Class 1 event data present on one or more of the RTU's event lists. This IIN flag is cleared when all Class 1 events have been cleared from the event lists.

**IIN1.2 Class 2 event data available in RTU**
The RTU sets this IIN flag in a response when there is buffered Class 2 event data present on one or more of the SCADAPack E event lists. This IIN flag is cleared when all Class 2 events have been cleared from the event lists.

**IIN1.3 Class 3 event data available in RTU**
The RTU sets this IIN flag in a response when there is buffered Class 3 event data present on one or more of the SCADAPack E event lists. This IIN flag is cleared when all Class 3 events have been cleared from the event lists.

**IIN1.4 Time synchronization required**
The RTU sets this IIN flag when the *Time Update Request Rate* timer has expired on the RTU. This IIN flag is cleared when the RTU time is set via a DNP3 Write request. **if NTP Network Time Synchronization is enabled in the RTU, the RTU will NOT set this IIN flag.**

**IIN1.5 RTU digital outputs in local state**
This IIN flag is not used by the RTU.

**IIN1.6 RTU device trouble**
This IIN flag is not used by the RTU.

**IIN1.7 RTU device has restarted**
The RTU sets this IIN flag when the RTU starts, or when the DNP3 driver in the RTU is restarted. The Master is responsible for clearing this flag via a DNP3 Write request.

**IIN Flags Second Byte (Request Errors)**
Bit #

**IIN2.0 Function Code not implemented**
The RTU sets this IIN flag in a response when the corresponding request message used a DNP3 Function Code that is not supported by the RTU. For more information see the *SCADAPack E DNP3 Slave Device Profile*.

**IIN2.1 Requested object(s) unknown**
The RTU sets this IIN flag in a response when the corresponding request message used a

DNP3 Object or Variation that is not supported by the RTU. For more information see *SCADAPack E DNP3 Slave Device Profile*.

**IIN2.2 Qualifier, range or data parameters invalid or out of range**
The RTU sets this IIN flag in a response when the corresponding request message used a DNP3 Qualifier Code, or an invalid DNP3 point index or point index range that is not supported by the RTU. For more information see *SCADAPack E DNP3 Slave Device Profile*.

**IIN2.3 Event buffer or application buffer overflow**
The RTU sets this IIN flag when event data has been removed from the RTU due to event list overflow. This flag is cleared automatically after having been reported in a response fragment.

**IIN2.4 Requested operation is already executing**
This IIN flag is not used by the SCADAPack E RTU.

**IIN2.5 Configuration corrupt**
The RTU sets this IIN flag under one of the following conditions:

- The RTU has no configuration
- The “CLEAR CONFIG” command is executed
- If the Profiler cannot find profile files required in the RTU point configuration
- If the RTU detects an error while reconfiguring the point database after a “RESTART CONFIG” command
- If the RTU detects an error while verifying the point database during RTU start-up

**IIN2.6 Reserved (0)**
This IIN flag is not used by the SCADAPack E RTU.

**IIN2.7 Reserved (0)**
This IIN flag is not used by the SCADAPack E RTU.

## 6.11 DNP3 Objects with Status Flags

The SCADAPack E RTU returns additional point information from the point database to the SCADA Master in DNP3 objects that support status flags.

Where status flag information is required, the RTU needs to be configured to send the appropriate DNP3 objects with status flags to the SCADA Master, and the SCADA Master needs to be capable of processing those objects.

The following DNP3 Object Status Flag bits are used by the RTU.

**Table 7.2: DNP3 Point Status Flags**

| Status Flag Bit Number | Description | SCADAPack E RTU Usage |
|---|---|---|
| [0] | On-line / Off-line | ON = On-line (Default)<br>OFF = Off-line: “Point Failed” property active |
| [1] | Restart | Not used by the RTU. OFF |
| [2] | Comm Lost | OFF = Point Communication OK (Default)<br>ON = Communication Lost: “I/O not responding” point property active |
| [3] | Remote Forced Data | This flag is not supported and is set to OFF. |
| [4] | Local Forced Data | This flag is not supported and is set to OFF. |
| [5] | Chatter Filter<br>[Binary Objects Only] | Used by SCADAPack ER Digital Input Module only |
| | Roll-over<br>[Counter Objects Only] | Not used as per DNP User Group recommendations.<br>OFF |
| | Over-range<br>[Analog Objects Only] | OFF = Point state normal (Default)<br>ON = Analog point value is Over / Under range |
| [6] | Reference Error<br>[Analog Objects Only] | OFF = Point state normal (Default)<br>ON = A/D Hardware Reference Error |
| [7] | Reserved | |

See following sections for specific DNP3 object use of status flags:


- ***Binary Input & Output Status Flags*** 48
- ***Analog Input Status Flags*** 49
- ***Counter & Analog Output Status Flags*** 50

### 6.11.1 Binary Input & Output Status Flags

## Binary Input Status Flags

| | | |
|---|---|---|
| On-line | = [0] <0,off-line; 1,on-line> | OFF-LINE = Point Is Failed (Property) |
| Restart | = [1] <0,normal; 1,restart> | NOT USED |
| Communication lost | = [2] <0,normal; 1,lost> | COMM LOST = I/O not responding |
| Remote forced data | = [3] <0> | This flag is not supported and is set to OFF. |
| Local forced data | = [4] <0> | This flag is not supported and is set to OFF. |
| Chatter filter | = [5] <0,normal; 1, filter on> | Supported on physical digital inputs of SCADAPack ER |
| Reserved | = [6] <0> | |
| State | = [7] <0, 1> | POINT STATE |

DNP3 “Binary Input” Data Objects access Physical Digital Inputs, User Digital points, System Digital points

## Binary Output Status Flags

| | | |
|---|---|---|
| On-line | = [0] <0,off-line; 1,on-line> | OFF-LINE = Point Is Failed (Property) |
| Restart | = [1] <0,normal; 1,restart> | NOT USED |
| Communication lost | = [2] <0,normal; 1,lost> | COMM LOST = I/O not responding |
| Remote forced data | = [3] <0> | This flag is not supported and is set to OFF. |
| Local forced data | = [4] <0> | This flag is not supported and is set to OFF. |
| Reserved | = [5] <0> | |
| Reserved | = [6] <0> | |
| State | = [7] <0, 1> | POINT STATE |

DNP3 “Binary Output” Data Objects access Physical Digital Outputs, User Digital points, System Digital points.

### 6.11.2 Analog Input Status Flags

| | | |
|---|---|---|
| On-line | = [0] <0,off-line; 1,on-line> | OFF-LINE = Point Is Failed (Property) |
| Restart | = [1] <0,normal; 1,restart> | NOT USED |
| Communication lost | = [2] <0,normal; 1,lost> | COMM LOST = I/O not responding |
| Remote forced data | = [3] <0> | This flag is not supported and is set to OFF. |
| Local forced data | = [4] <0> | This flag is not supported and is set to OFF. |
| Over-range | = [5] <0, normal; 1, over-range> | ** see Table below |
| Reference check | = [6] <0, normal; 1, error> | ERROR = A/D Reference Error |
| Reserved | = [7] <0> | NOT USED |

DNP3 “Analog Input” Data Objects access Physical Analog Inputs, User Analog points, System Analog points

**The *Over-Range* analog input status flag is set when either an *Over-Range* or *Under-Range* point property is set. The following table describes the value returned in the DNP object for over-range and under-range conditions:

**Table 7.3: Under and Over Range Conditions for Analog Inputs Types**

| Point Object Type | Condition | Value Returned |
|---|---|---|
| 16-bit Analog Input | Under-Range | -32768 |
| 16-bit Analog Input | Over-Range | +32767 |
| 32-bit Analog Input | Under-Range | $-2^{31}$ |
| 32-bit Analog Input | Over-Range | $+2^{31}-1$ |
| Float Analog Input | Under-Range | –FLT_MAX* |
| Float Analog Input | Over-Range | FLT_MAX* |

* FLT_MAX = 3.402823e+38

It is the responsibility of the SCADA master to determine whether an actual over-range or under-range has occurred based on the DNP3 Over-range flag and point value.

### 6.11.3 Counter & Analog Output Status Flags

## Counter Status Flags

| | | |
|---|---|---|
| On-line | = [0] <0,off-line; 1,on-line> | OFF-LINE = Point Is Failed (Property) |
| Restart | = [1] <0,normal; 1,restart> | NOT USED |
| Communication lost | = [2] <0,normal; 1,lost> | COMM LOST = I/O not responding |
| Remote forced data | = [3] <0> | NOT USED |
| Local forced data | = [4] <0> | NOT USED |
| Roll-over | = [5] DNP3 Subset recommendation not to use | |
| Reserved | = [6] <0> | NOT USED |
| Reserved | = [7] <0> | NOT USED |

DNP3 *Counter* Data Objects access Counters on Physical Digital Inputs, User Analog points and System Analog points whose DNP Object Type attribute is set to a DNP3 Counter Object / Variation.

Roll-over is not supported by the SCADAPack E RTU Counters, as per the recommendation in the DNP3 subset in order to promote counter inter-operability. It is up to the SCADA Master to determine counter roll-over based on knowledge of previous counter value.

## Analog Output Status Flags

| | | |
|---|---|---|
| On-line | = [0] <0,off-line; 1,on-line> | OFF-LINE = Point Is Failed (Property) |
| Restart | = [1] <0,normal; 1,restart> | NOT USED |
| Communication lost | = [2] <0,normal; 1,lost> | COMM LOST = I/O not responding |
| Remote forced data | = [3] <0> | This flag is not supported and is set to OFF. |
| Local forced data | = [4] <0> | This flag is not supported and is set to OFF. |
| Reserved | = [5] <0> | NOT USED |
| Reserved | = [6] <0> | NOT USED |
| Reserved | = [7] <0> | NOT USED |

*Output* Data Objects access Physical Analog Outputs, User Analog points, System Analog points.

## 6.12 Virtual Terminal Support

The RTU supports DNP3 Virtual Terminal objects (hereafter referred to as VT objects) as specified in the *SCADAPack E DNP3 Slave Device Profile*. This section details how the Virtual Terminal objects are supported in the RTU. The processing of transactions that contain VT objects is dependent on the VT port number (point index) specified in the transaction.

In general, the DNP3 Virtual Terminal protocol allows passing of unstructured data between Master and Slave sides of a DNP3 communication link, allowing local terminal interfaces on specific IEDs to be accessed remotely using the DNP3 Virtual Terminal objects. The result is a transparent exchange of data.

SCADAPack E RTUs also support **TCP Service Ports**. Information on these can be found in the *SCADAPack E TCP/IP Technical Reference* manual.

### Virtual Terminal Object Summary

***Object Group***

The DNP3 virtual terminal objects allow specification of an output block object (object group 112) that is sent using a DNP3 WRITE (FC 2), and an event object (object group 113) that can be returned in an UNSOLICITED RESPONSE (FC 130), or in RESPONSE (FC 129) to a READ (FC 1) request.

***Variation***

The DNP3 *variation* field specifies the length of the "user data" in the virtual terminal object. The maximum user data sizes with respect to the SCADAPack E are detailed in Section ***Virtual Terminal Object Data Sizes*** 52.

***Qualifier / Range***

The *qualifier* to be supported for VT transactions is dependent on the object, where requests referencing object 112 and object 113 shall use qualifier 0 (8-bit Start and Stop Indexes) or qualifier 0x17 (8-bit quantity), and responses referencing object 113 shall use qualifier 0x17 (8-bit quantity). The index value shall represent the VT port number. Valid VT port numbers range from 0 – 255.

The VT port numbers currently supported by the SCADAPack E RTU firmware are listed as follows

- VT Port 0 — ISaGRAF Remote Debugging. Refer to Section ***ISaGRAF Remote Debugging (VT Port 0)*** 52
- VT Ports 10 – 19 — DNP VT Service Port Functions. Refer to Section ***DNP3 VT Service Ports (VT Ports 10 – 19)*** 53
- VT Port 20 — Remote Command Line. Refer to Section ***Remote Command Line (VT Port 20)*** 52

### 6.12.1 ISaGRAF Remote Debugging (VT Port 0)

## ISaGRAF Remote Debugging (VT Port 0)

Virtual Terminal port 0 is reserved *ISaGRAF Remote Debugging* allowing ISaGRAF Workbench to communicate with an ISaGRAF target kernel in a remote RTU over a DNP3 communications link (consult the *SCADAPack E Configurator Users Manual* for more information).

### 6.12.2 Remote Command Line (VT Port 20)

## Remote Command Line (VT Port 20)

Virtual Terminal port 20 is reserved for the “Remote Command Line” interface. This interface presents the standard RTU command line interface to remote users across DNP3 communication links using virtual terminal objects 112 and 113 (over VT port 20). The SCADAPack E Configurator provides a “Remote Command Line (Virtual Terminal)” window to access this functionality in the RTU Consult the *SCADAPack E Operational Reference* manual for more information regarding the “Remote Command Line” functionality in the RTU.

### 6.12.3 Virtual Terminal Object Data Sizes

This section details the maximum “user data” sizes for inclusion in a single VT object (i.e. object 112 or 113). These sizes may determine any fragmentation and subsequent latencies of the request / response messages.

## Maximum Received User Data Size

The maximum request size, i.e. unstructured user data, supported in a single VT object has been based around inclusion in a single DNP3 frame. The RTU will accept a maximum received frame size of 292 bytes (including frame header, CRCs, etc.). **Therefore a maximum of 240 bytes of VT “user data” can be sent in a single DNP3 frame** to comply with the recommendations of the DNP3 standard. The recommendation limits the size of VT user data to 240 bytes so the transmission can be received by memory-limited devices.

## Maximum Transmitted User Data Size

The maximum response size, i.e. unstructured user data, supported in a single VT object has been based around inclusion in a single DNP3 frame, therefore the maximum response size that can be transmitted in a single DNP3 frame from the RTU is 249 bytes (including frame header, CRCs, etc.). **This corresponds to a maximum of 201 bytes of VT user data** that can be included in a DNP3 frame. Due to this object size limitation, the maximum amount of VT user data that may be transmitted (from the SCADAPack E RTU ) in a single DNP3 fragment is ~ 2010 bytes.

When using VT transactions with SCADAPack 300E controllers, individual transactions should be **limited to 1K bytes**. Data may be missing for transactions larger than this.

### 6.12.4 DNP3 VT Service Ports (VT Ports 10 - 19)

Virtual Terminal transactions received from the DNP3 protocol for VT port numbers 10-14 will be forwarded to the appropriately configured serial port (Port 0 through Port 4) as shown below.

Data received on the serial port will be forwarded to the configured DNP3 master station either in a READ response, a class 3 poll response or an Unsolicited Response (depending on RTU configuration).

The specified VT Port number will determine which serial port the data should be directed to.

**NOTE:** When using VT transactions with SCADAPack 300E controllers, individual transactions should be **limited to 1K bytes**. Data may be lost for transactions larger than this.

VT port numbers for the *DNP VT Service* ports are as follows:

## Virtual Terminal Port Numbers

As noted in ***Virtual Terminal Support*** 51, the specified index for objects 112 and 113 represents the Virtual Terminal Port Number. The Virtual Terminal Port Number is mapped to a configured RTU serial port. The following VT port numbers are used for mapping to the SCADAPack E RTU serial ports

- VT Port 10 <===> RTU Port 0
- VT Port 11 <===> RTU Port 1
- VT Port 12 <===> RTU Port 2
- VT Port 13 <===> RTU Port 3
- VT Port 14 <===> RTU Port 4
- VT Port 15 – 19 – Reserved for future use.

The following sections details the DNP3 transactions used to transport the “user data” on the virtual terminal port.

A message originating from the DNP3 Master is referred to as a “*VT request transaction*”.

A message received on the ***DNP VT Service Port*** is referred to as a “*VT response transaction*”.

- Processing of VT Request Transactions, VT Service Port Event Buffers, & RTU Serial Port Configurations 54
- Processing of VT Response Transactions 55

### 6.12.4.1 Processing of VT Request Transactions, VT Service Port Event Buffers, & RTU Serial Port Configurations

## Processing of VT Request Transactions

The following analysis of a *VT request transaction* is based on a single DNP3 VT message from a DNP3 Master to an SCADAPack E RTU.

- The inbound DNP3 message received by the RTU (**for that RTU)** from the DNP3 Master is a WRITE (FC 2) for object 112.
- The RTU responds to request with IINs in its response only, i.e. no data. If the index does NOT map to an RTU "DNP VT Service" port, the RTU responds with a "parameter out of range" IIN.
- If the specified index is for a ***DNP VT Service*** port, the RTU will send the user data included in the request to the respective ***DNP VT Service*** port.

## VT Service Port Event Buffers

The Virtual Terminal event buffers are volatile, i.e. a Warm or Cold Reset of the RTU will result in the clearing of any buffered VT event data (received on a DNP VT Service Port).

The RTU allows for a maximum of 100 VT event objects to be stored, i.e. maximum user data storage of approximately 20 KB.

If VT event data is lost, the RTU error code system point will be set with an error code as described in ***Error Conditions*** 59 **[Loss of Virtual Terminal Event Data]** 59.

The VT event buffers can be remotely purged using the RTU command "*clear vt_events*".

This allows clearing of VT events without impacting the standard DNP3 event buffers, i.e. binary, analog and counter events. This can be executed remotely using the DNP3 FILE EXEC command, or alternatively, the VT event buffers can be purged by executing this command directly at the command line (or TELNET).

## RTU Serial Port Configurations

In order to support Virtual Terminals, the appropriate SCADAPack E RTU port function needs to be set the ***DNP VT Service*** port. The RTU simultaneously supports multiple ***DNP VT Service*** ports, so any combination of controller serial ports can be set for *DNP VT Service* mode.

The Virtual Terminal Port Numbers that map to controller serial ports are detailed in Section ***DNP3 VT Service Ports (VT Ports 10 – 19)*** 53.

#### 6.12.4.2 Processing of VT Response Transactions

The processing of the *VT response transaction* is depends on the configuration of Unsolicited Responses for object 113. The processing of *VT response transactions* via solicited RESPONSEs (FC 129) or UNSOLICITED RESPONSEs (FC 130) are described separately in the following sections. By default, object 113 events are internally assigned to be CLASS 3.

- ***Enabling / Disabling Unsolicited Responses On Object 113 & VT Response Transaction in DNP3 Unsolicited Response (FC 130)*** 56
- ***'Packet' Determination for Responses & VT Response Transaction in DNP3 Request Response (FC 129)*** 58

#### 6.12.4.2.1 Enabling / Disabling Unsolicited Responses On Object 113 & VT Response Transaction in DNP3 Unsolicited Response (FC 130)

### Enabling/Disabling Unsolicited Responses on Object 113

The factory default (FC) configuration of the SCADAPack E RTU specifies that Unsolicited Responses are disabled for every class / object. Unsolicited Responses can be enabled for VT event objects (object 113) in one of 2 ways.

- An ***Enabled Event Class*** configuration value that includes "**Class 3**" enables Unsolicited Responses for VT event objects.
- An ENABLE UNSOLICITED RESPONSES (FC 20) message for object 113 enables Unsolicited Responses for VT event objects. A DISABLE UNSOLICITED RESPONSES (FC 21) message for object 113 **disables** Unsolicited Responses for VT event objects.

### VT Response Transactions in DNP3 Unsolicited Response (FC 130)

The *VT response transaction* analysis detailed in this section assumes that UNSOLICITED RESPONSES have been enabled in the SCADAPack E RTU.

- Inbound data is received by the RTU on a ***DNP VT Service*** port.
- The RTU "collects" this data which is buffered in VT event objects, i.e. obj 113.
- The RTU will continue to collect this data until the criteria for generating an UNSOLICTED RESPONSE has been satisfied. This criterion is specified in Section ***'Packet' Determination for Responses*** 58.
- On satisfying this criterion, the RTU will then attempt to generate an Unsolicited Response for the VT event objects.
- The appropriate application layer CONFIRM will delete the event objects that were transmitted in the preceding Unsolicited Response.

The Unsolicited Response mechanism used for VT event objects does not conform to the standard rules for the RTU. This is because the normal configurable timing parameters are inappropriate for transmission of VT event object in Unsolicited Responses. The following rules apply to "VT event object" Unsolicited Responses.

- The "***Min. Unsol. Event Tx Delay***" or the ***"Event Notification Delay"*** are not used for VT Unsolicited Responses. Collection of data before an Unsolicited Response is attempted, is based on "*the amount of data collected*" and / or "*time since last data received*".
- The "***Appl. Layer Confirm (Event) Timeout***" will apply to VT Unsolicited Responses. The minimum value for this configuration is dependent on the Data Link configurations of the Master Port.
- If the RTU determines that an Unsolicited Response is to be generated because of standard event data (i.e. binary, analog or counter events), then the VT event data may also be included in the Unsolicited Response.
- If the RTU determines that an Unsolicited Response is to be generated because of VT event data, then any standard event data will only be included in the Unsolicited Response, if the "***Min. Unsol. Event Tx Delay***" has transpired since the last Unsolicited Response containing standard event data (i.e. normal criteria for generating Unsolicited Responses for standard event data).
- No Unsolicited Responses will be generated if the RTU is waiting for an application CONFIRM from the master.

The unsolicited response will be directed to the ***master*** DNP address, on the current Master communication interface. Not that the Master communication interface is specified in the RTU's

configuration, though if the RTU ‘hears’ from the Master on another interface, it will then direct the Unsolicited Responses on this “updated” interface.

#### 6.12.4.2.2 'Packet' Determination for Responses & VT Response Transaction in DNP3 Request Response (FC 129)

## 'Packet' Determination for Responses

The SCADAPack E RTU needs to decide what constitutes a 'packet', i.e. amount of data to include and when to try and send it. To some degree it depends on the response type, i.e. Solicited or Unsolicited. For a Solicited response (to an appropriate request), the RTU will return any buffered VT event data, up to a complete response fragment. However if there are no outstanding requests for VT event data, and data is being collected from the ***DNP VT Service*** serial port, the RTU needs to determine when an Unsolicited Response should be generated (assuming Unsolicited Responses have been enabled for object 113). The RTU will attempt to generate an Unsolicited Response based on either of the following criteria (whichever occurs first)

- A complete 2kB fragment of data has been collected.
- An inactive period has transpired where no data collected from *DNP VT Service* port (e.g. time to transmit 20 characters - dependent on baud rate).

## VT Response Transaction in DNP3 Request Response (FC 129)

The application layer request may either be a READ (FC 1) request specifically for VT event objects (i.e. object 113) or for class 3 event data (object 60 var 4).

- Inbound data is received by the RTU on a ***DNP VT Service*** port.
- The RTU "collects" this data which is buffered in VT event objects, i.e. obj 113.
- Any response issued to the DNP3 master not including this data will have the ***class 3 data available*** IIN set (due to object 113 event data).
- An appropriate request (i.e. READ request for object 113 or class 3 event data) will invoke a response which will include the object 113 event data. If the data spans more than 1 fragment, the RTU will only return a single fragment. The ***class 3 data available*** IIN will be set to indicate that there are more VT event objects (object 113) to be collected.
- An application layer CONFIRM will be requested by the RTU response, as the response contains event data. Arrival of the CONFIRM will cause the RTU to delete the event objects that were transmitted in the preceding response.

The response fragment will be directed to the ***source*** DNP address specified in the request, on the same communication interface on which the request message was received.

#### 6.12.4.3 Error Conditions

This section details any error conditions that may arise as a result of processing *VT request transactions* and / or event buffer storage limitations.

### VT Port Number Error

As noted in Section ***DNP3 VT Service Ports (VT Ports 10 – 19)*** 53 the VT port number maps to the appropriately configured ***DNP VT Service*** port. If the VT port number specified in the *"VT request transaction"* does NOT map to an appropriately configured serial port, the application layer response issued to the WRITE request will have the "***parameter out of range***" IIN set.

### Loss of Virtual Terminal Event Data

The maximum number of VT event objects that can be buffered is 100. If the VT event buffers are filled and VT event is lost, the RTU Error Code System Point will be controlled with the value 1035, i.e. ***VT EVENT DATA LOST***. The ***Event Buffer Overflow*** IIN will also be set by the RTU in any application layer responses.

## 6.13 Resetting and Presetting Counters

The SCADAPack E RTU supports the following DNP3 protocol function codes with counter objects:

- 15 – INITIALIZE DATA. Issuing a DNP3 application request for this function code clears the value of the RTU point with the specified DNP3 counter point index(es).
- 1 – READ. This function code is used when reading the current value (and statuses) of counter objects.
- 2 – WRITE. This function code is used when presetting and/or clearing counter values.

The use of these function codes are supported on the SCADAPack E RTU Physical Counter Input points, and RTU Analog user points whose “DNP3 Object Type” attribute is set as a DNP3 Counter object.

SCADAPack ES Remote I/O unit Counters cannot be preset to a value other than 0 when using a DNP3 Write commands to a Counter object. A write to a counter object on a remote I/O unit with a non-zero value will result in the counter value being preset to 0 (equivalent to clearing the value using the INITIALIZE DATA function code).

One of the following DNP3 application requests may be used:

**Table 7.4: DNP3 Counter Function Codes**

| FC | GROUP | VAR | QUALIFIER | | | Comment |
|---|---|---|---|---|---|---|
| 15 | 20 | 0 | 06 | | | Clear value of RTU points set with DNP3 counter objects. Counter Point 0 is not supported with FC 15 and qualifier 06. |
| 15 | 20 | 0 | 00 | Start | Stop | Clear value of specified range of DNP3 counter object points (8-bit Start/Stop Indexes) |
| 15 | 20 | 0 | 01 | Start | Stop | Clear value of specified range of DNP3 counter object points (16-bit Start/Stop Indexes) |
| 2 | 20 | 1, 2, 5, 6 | 00, 01 | Start | Stop | Set value of specified range of DNP3 counter object points (either: 8-bit Start/Stop Indexes or 16-bit Start/Stop Indexes) |
| 1 | 20 | 1, 2, 5, 6 | 00, 01 | Start | Stop | Read value of specified range of DNP3 counter object points (either: 8-bit Start/Stop Indexes or 16-bit Start/Stop Indexes) |

The RTU Physical Counter points may also be configured to automatically reset upon restart of a Main RTU. For more information see the *SCADAPack E Data Processing Technical Reference*.

## 6.14 DNP3 Multi-Master Feature & Events

The SCADAPack E RTU can support multiple DNP3 masters, whereby each DNP3 master is identified by the RTU with respect to *DNP Master address*, *Master Port* and *Point Data Class* on a per-point basis.

The RTU firmware supports a maximum of 3 DNP masters as indicated on SCADAPack E *DNP Masters* page. The DNP3 Multi-Master firmware is a licensed feature as indicated on the *General / Controller Status* page of SCADAPack E Configurator. A sample screen shot is given in ***Figure 7.18*** 61 . Only the "Master 1" parameters are applicable if the "Supports Multiple DNP3 Masters" feature is not licensed.

**Figure 7.18: Indication of DNP Multiple Master License**

The *Point Data Class* common point attribute has been extended such that it is now configurable on a per-Master basis as illustrated in ***Figure 7.19*** 62. This allows the RTU to present a different "view" of its non-local points to different DNP Masters. This may have applications in local HMI situations or for RTUs used for custody transfer.

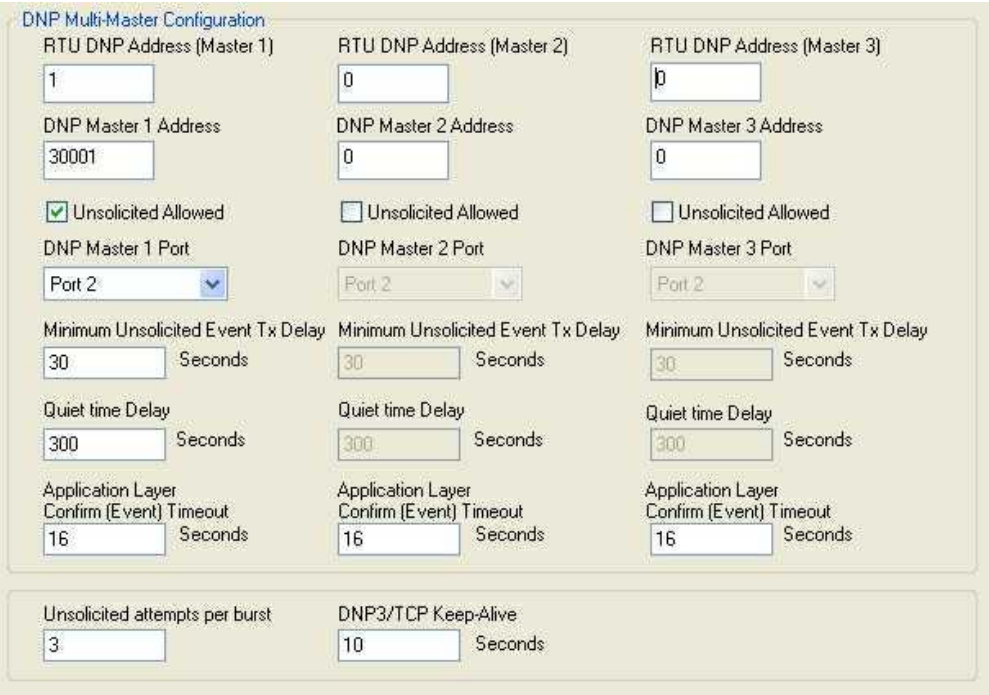



**Figure 7.19: Multi-Master Configuration points**

Some configuration parameters applicable to Multi-master operation, and located on the *DNP Masters* page of the SCADAPack E Configurator, are shown in ***Figure 7.19*** 62 and further explained below:

**DNP Master Address**
This parameter configures the DNP3 Node Address of the DNP3 Master (typically the SCADA Master), to which the RTU may report Unsolicited Responses. A value of zero means "No Master" for Master sessions 2 and 3.

**DNP Master Port**
This parameter configures the port on which the RTU sends Unsolicited Responses to the master station.

**Min. Unsol. Event Tx Delay**
This parameter sets the minimum time (in seconds) between consecutive Unsolicited Responses sent from the RTU to the SCADA Master. After an Unsolicited Response has been sent by the RTU, no Unsolicited Response will be generated until this time period has elapsed.

**Quiet Time Delay**
This parameter is the "offline" *Min. Unsol. Event Tx Delay time.* This value is applied when the number of timed-out Unsolicited Responses reaches the *Unsol. Attempts per burst* count. These parameters allow the RTU to implement "burst-mode" where the RTU retries several times, waits for an extended time period, and then begins another burst of Unsolicited retries. This behavior is repeated indefinitely until an Application Layer confirmation is received.

**Appl Layer Confirm (Event) Timeout**
This parameter sets the time (in seconds) that the RTU expects a DNP Application Layer Confirm message from the master after the RTU has transmitted event data (either in a poll response or unsolicited response). The "Data-Link Layer Confirm Mode" and "Data Link Timeout" parameters are used to calculate a minimum value for this timeout. The RTU will automatically apply the minimum timeout if this parameter is set too low.

If an Application Layer Confirm is not received from the master within the timeout period, then the greater of this value and the *Min Unsol TX Delay* parameter (see above) is used to delay the transmission of new unsolicited event data to the master.

**DNP Local Address**
This parameter allows the DNP Address of the RTU to be configured. The value for Master 1 is the same setting as that found on the SCADAPack E Configurator *Ports* page. The values for Masters 2 and 3 allow the RTU to respond to the respective DNP Master address with a different local address. This is required by some Master stations that can not configure different "logical" RTU's with the same DNP address. Zero is a valid entry for these fields.

**Unsol. Allowed**
This checkbox controls the Unsolicited Response mode (either on or off). When unsolicited response operation is configured off, the RTU will not send an unsolicited response to the respective Master, but otherwise responds to Master requests.

**DNP3/TCP Keep-Alive**

This parameter is implemented as described by the DNP User Group's "*Transporting DNP3 over Local and Wide Area Networks*" standard. It is a configurable Keep-Alive timer is used for each active DNP3 - TCP socket connection. This configuration parameter specifies how often a DNP3 Link Status test message is sent across active TCP sockets for the purpose of verifying an active TCP link. This timer may be set to "0" to de-activate the DNP-TCP Keep-Alive timer.

## DNP3 Multi-Master Events

The RTU's IO Processor creates time stamped change events and passes them along to the DNP3 task for storage and later transmission (see the *SCADAPack E Data Processing Technical Reference Manual* for more details). The DNP3 Multi-Master firmware only stores one copy of each event in non-volatile memory, regardless of how many Master sessions are enabled. An event is only deleted when every enabled Master has confirmed the event (assuming that the point was configured as Event Class 1, 2 or 3 for each Master). For this reason, it is recommended that Master sessions are not enabled where no DNP3 Master station actually exists. Otherwise, non-volatile event storage will continue to grow to the maximum allowed by the RTU.

## 6.15 DNP3 Operation Using TCP/IP, Routing for TCP/IP

### DNP3 Operation Using TCP/IP

The SCADAPack E RTU's DNP3 protocol operation over TCP/IP conforms with the requirements of the DNP User Group's "*Transporting DNP3 over Local and Wide Area Networks*" document. Assigned TCP and UDP port number "20000" is used for DNP3 communications.
Both a UDP socket listener and TCP socket listener are installed on the RTU for DNP3 communications. The sockets listened for are set by the "Default DNP3 Port" parameter (see below). Communication on both UDP and TCP sockets may be active simultaneously, and multiple external TCP/IP devices may concurrently request connections to the TCP socket, or send datagrams to the UDP socket.

PPP-TCP/IP processing and communication across local area and wide area networks may introduce additional delays in transporting DNP3 frames. Increasing DNP3 Data Link Layer and Application Layer time-outs in DNP3 devices, particularly across PPP links on WAN networks, may need to be considered.

### DNP3 Routing for TCP/IP

The SCADAPack E can behave as standard DNP3 slave devices and respond to DNP3 Master requests on DNP3 serial channels, Ethernet-TCP/IP and PPP-TCP/IP channels.

HINT: In a network consisting of DNP3 nodes separated by IP networks, it is simplest to consider Ethernet-TCP/IP and PPP-TCP/IP channels between RTU devices as transparent.

Where DNP3 frames are routed via TCP/IP on the SCADAPack E RTU, individual routing entries may be added to the DNP3 Route Table which can specifically override the use of TCP transport, or UDP transport including port numbers. These overrides are described further in Section ***DNP3 TCP/IP Networking*** 76 **(DNP3 Network Forwarding with TCP/IP)** 76. Where these overrides are not applied, the parameters described in Section ***DNP3 - TCP Keep-Alive Timer*** 67 are used as the default communication settings.

## 6.16 DNP3 Link Layer Settings for TCP/IP

- For PPP interfaces on the SCADAPack E RTU, the following DNP3 Data Link Layer facilities may be configured:

| | | | |
|---|---|---|---|
| DNP3 Data Link (DL) Mode: | Never | | |
| | Sometimes | } | DNP3 DL Confirm Timeout |
| | Always | } | DNP3 DL Retries |

PPP-TCP/IP processing and communication across local area and wide area networks may introduce additional delays in transporting DNP3 frames. Increasing DNP3 Data Link Layer and Application Layer time-outs in DNP3 devices, particularly across PPP links on WAN networks, may need to be considered.

Using SCADAPack E Configurator, adjust these serial port parameters from the *DNP3 Comms* page as illustrated in the figure below.

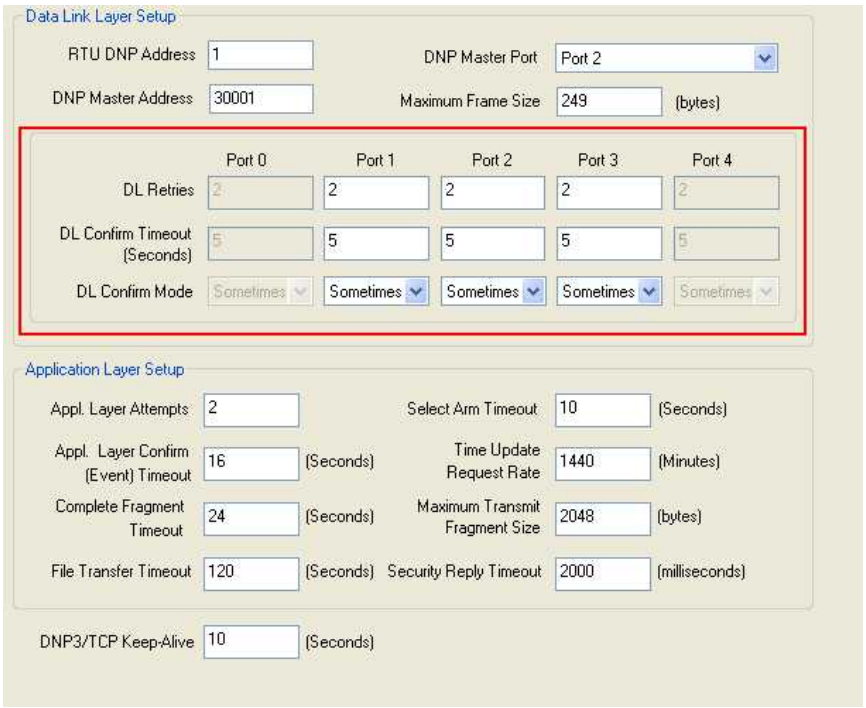



**Figure 7.20: Serial Port Data Link Layer Settings for DNP3**

For the RTU Ethernet interface, the following DNP3 Link Layer facilities may be configured. The default Data Link Layer mode as required by the DNP User Group's "*Transporting DNP3 over Local and Wide Area Networks*" document is *Never* mode. Using SCADAPack E Configurator, adjust these Ethernet port settings from the *Advanced TCP/P* page as illustrated:

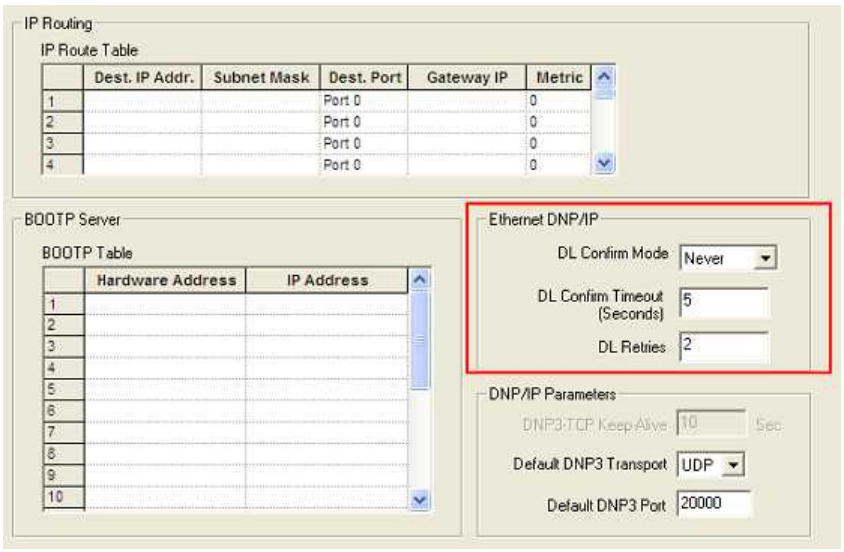



**Figure 7.21: Ethernet Data Link Settings for DNP3**

## 6.17 DNP3 - TCP/IP Settings

### Default DNP3 Transport

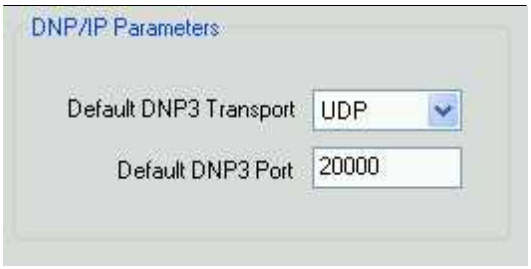



**Figure 7.22: Default DNP3 Transport Dialog**

This parameter may be set to either “UDP” or “TCP” and sets the default transport protocol used for conveying out-bound DNP3 protocol frames across LAN/WAN links. Where a DNP3 route table entry does not contain override information, the setting of this parameter determines whether UDP or TCP transport is used for out-bound DNP3 LAN/WAN communications. This parameter is configured from the *Advanced TCP/IP Page* of the SCADAPack E Configurator.

### Default DNP3 Port

This parameter sets the UDP Port Number and TCP Port Number that is used as the default for transporting DNP3 protocol frames across LAN/WAN links. For in-bound access to SCADAPack E RTU sockets for DNP3 communication, the setting of this parameter determines the port number used by the TCP and UDP socket listeners for DNP3 LAN/WAN communications.

Where a DNP3 node route table entry does not contain override information for out-bound communication, the setting of this parameter in conjunction with the “Default DNP3 Transport” parameter, determines the port number and transport used for out-bound DNP3 LAN/WAN communications. Normally this parameter is set to “20000”, being the DNP User Group’s assigned number for DNP3 communications for internet networks.

### DNP3-TCP Keep Alive Parameter

See DNP3 Application Layer Configurations 15.

## 6.18 DNP3 TCP/IP End-Node Operation

Where a SCADAPack E RTU is an end-node in a TCP/IP network and DNP3 communication is used, the following parameters need to be set for correct operation with a DNP Master Station.

- RTU DNP Address — DNP3 node address of this RTU
- DNP Master Address — DNP3 node address of Master station
- DNP Master Port — IP interface port that has access to Master station network (e.g. SCADAPack E RTU serial port enabled for PPP, or Ethernet interface)
- IP Address / Subnet — local SCADAPack E settings for IP interface(s)

Mask

- DNP Node Route Table — entry for Master Address including IP information in “Connect No.” field*
- Ethernet DNP/IP Data Link: — data link settings for DNP3 over Ethernet

  DL Confirm Mode - usually 'Never'

  DL Confirm Timeout - } see Section ***DNP3 Data Link Layer Configurations*** 12

  DL Retries - }
- DNP/IP Default DNP3 Transport — set same as Master station’s transport (TCP or UDP) unless the “Connect No.” field overrides this.
- DNP/IP Default DNP3 Port — set the same as Master station’s UDP or TCP port number unless the “Connect No.” field overrides the UDP port number.
- Appl. Layer Confirm (Event) Timeout — when sending events to the DNP Master, sets the timeout within which time a confirm needs to be received from the DNP Master.

* For information on the use of “Connect No.” field for IP networking, see Section ***DNP3 TCP/IP Networking*** 76 **(DNP3 Network Forwarding with TCP/IP)** 76.

## 6.19 Controlling DNP3 Master Communications

This sections describes specific functionality whereby communications to a configured DNP3 Master station may be disabled or enabled in the RTU.

*Disabling DNP3 Master Communications* can be carried out analog system points as shown in the table below, or by using the ISaGRAF RTUPARAM function block. Using the system points allows communication to be inhibited on startup, as the ISaGRAF kernels will not run until the DNP3 driver is fully initialized. DNP3 master communications may have already been established before the ISaGRAF application may be used to disable DNP3 Master communication.

*Enabling DNP3 Master Communications* can be carried out using the ISaGRAF RTUPARAM Function Block.

### DNP3 Master Communications Control using ISaGRAF

**Table 7.5: DNP3 Master Communications Disable System Points**

| Point Name | Point Type | Point Number |
|---|---|---|
| DISABLE MASTER 1 AT STARTUP | Analog | 63420 |
| DISABLE MASTER 2 AT STARTUP | Analog | 63421 |
| DISABLE MASTER 3 AT STARTUP | Analog | 63422 |

Controlling these system points with a non-zero value will inhibit communications to the relevant DNP3 master station on the next restart of the RTU. The default values for these system points is 0.

If communications to a configured DNP3 Master has been inhibited (via these system points), the RTU will NOT respond to any DNP3 messages received from that Master address, and the RTU will NOT generate any Unsolicited Responses for that DNP3 Master.

# 7 DNP3 Networking

Each SCADAPack E RTU node has a unique *DNP3 Node Address*, which needs to be set in the *RTU DNP Address field*. A screen capture of this field from SCADAPack E Configurator Ports page is displayed below.

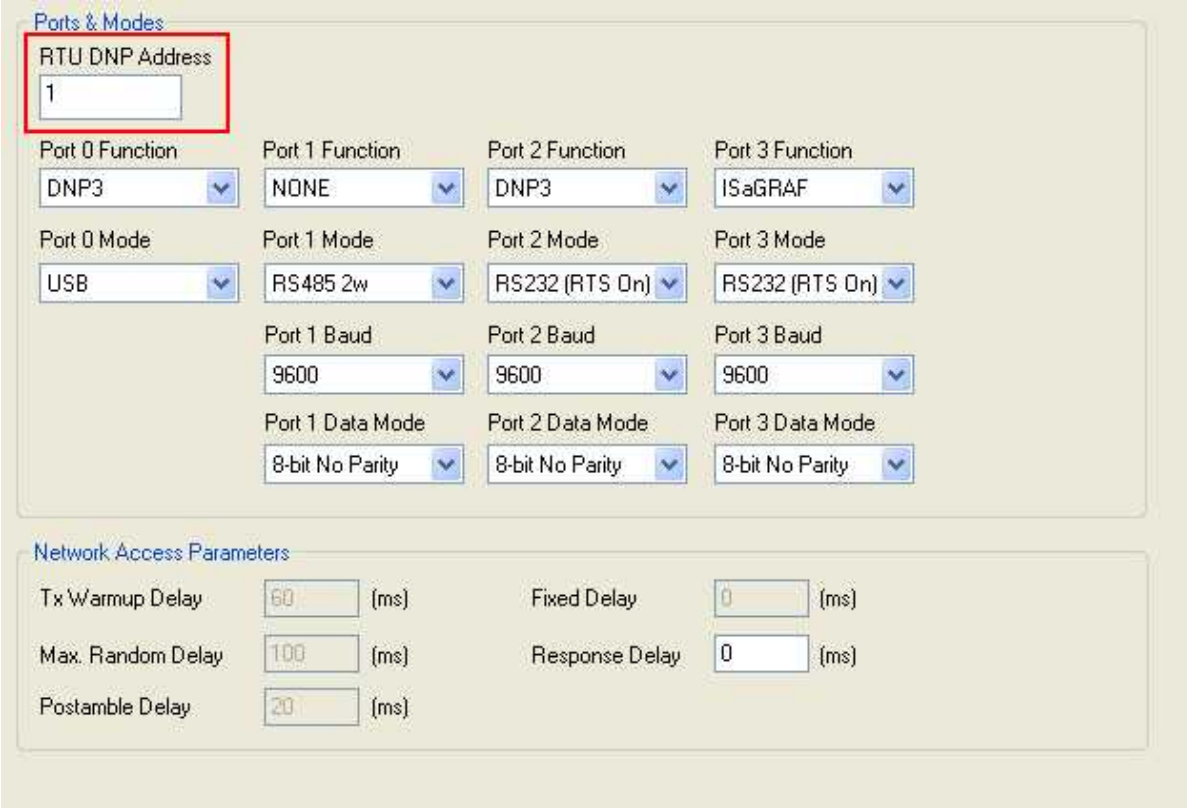



**Figure 6.1: SCADAPack E Configurator RTU DNP Node Field**

The range of *RTU DNP Node Address* values is 0-65519. It is recommended, however, that node address "0" not be used in field SCADAPack E RTUs for the following reasons:

- "0" is the default node address when SCADAPack E RTUs are shipped from the factory and after COLD BOOT initialization
- "0" is the assumed node address in the SCADAPack E RTU when MAINTENANCE BOOT mode is applied. (For more information see *SCADAPack E Operational Reference* manual)
- The SCADAPack E RTU uses value "0" to terminate searches of some its internal lists

Communications to be sent from the RTU to a DNP Master are assigned a communication port by putting an entry in the "DNP Master Port" field as described later in this section of the manual. Other communications is directed to RTU communication ports based on routing.

Each DNP3 data-link layer frame contains both a Source and Destination DNP node address. This addressing scheme allows peer-to-peer RTU communication, and allows DNP data-link layer frames to be routed.

The SCADAPack E RTU DNP networking functions perform the following:

- Pass a DLL frame with this DNP Node destination address to the Transport layer (including

Broadcast frames – destination addresses 65520-65535 = FFF0-FFFF hex).

- Determine if the destination node for a received DLL frame appears in the network routing table. If so, pass frame back to the DLL layer for transmission on a given DNP physical channel.
- Discard the DLL frame if not for this node & not to be forwarded to another node.

The SCADAPack E RTU determines how to route DNP3 data link frames by using a Network Routing Table. Each RTU can be configured with a network routing table and route DNP packets. Typically, though, only a small number of nodes in a DNP network are required to route frames. These nodes usually have two or more DNP3 communication ports, and a unique routing table.

A screen capture of the DNP Node Routing Table located in the *DNP Network* page of SCADAPack E Configurator is presented below.

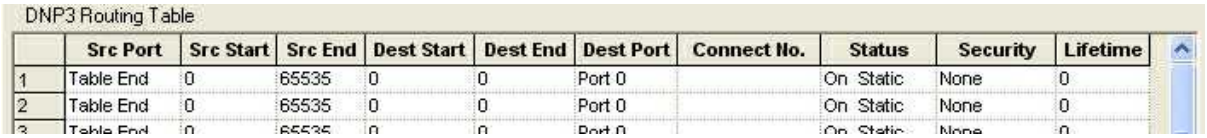



**Figure 6.2: SCADAPack E Configurator DNP Node Routing Table**

The DNP Network Routing Table is organized in rows. Each row contains one route table entry and describes one scenario for routing a DNP frame received at this node. Some routes may require connection numbers.

The column headings in the routing table is explained below:


- ***Static & Fixed Routing*** 72
- ***Dynamic Routing & Routing Rules*** 74
- ***DNP3 TCP/IP Networking*** 76

## 7.1 Static & Fixed Routing

### Static Routing

By default, entries manually added to the DNP Node Routing table are ONLINE STATIC route entries and are maintained in non-volatile memory by the RTU.

The fields comprising each route table entry are:

*Source Port:* The RTU port from which the DNP frame needs to arrive for this entry to be valid. May be any of the following values:

**Table End** (End of Route Table)
**Any** (received on any port)
**Port 0 ~ Port 8, Ethernet 1, Ethernet 2**

*Source DNP Addr:* The range of DNP addresses from which the frame needs to have originated in order for this entry to be valid. An entry of **0 – 65535** means the frame may originate from ANY DNP3 node.

The *Source Port & Source DNP Address* fields are not required in many circumstances. Common values are ANY and 0-65535, respectively meaning the packet may originate anywhere in the network and be routed by this SCADAPack E RTU. Store & Forward routing in some network architectures, for example, can make use of the source port & address facilities of the SCADAPack E DNP Network Routing Table. They can also be used to partition networks and stop RTUs on different networks from communicating with each other.

The following fields for each route table entry are used:

*Destination DNP Addr:* The range of DNP addresses to which the frame needs to be destined in order for this entry to be valid.

*Destination Port:* The communication port that this RTU will route the received packet *TO* if the source port, source address & destination address fields match the received packet. It may have any of the following values:

**Port 0 ~ Port 8, Ethernet 1, Ethernet, 2**

Static routes may require connection numbers in order to connect to the required DNP device. Connection numbers are required for the following *Destination Port* configurations

- when the *Destination Port* is an IP Port (e.g. Ethernet or PPP), the *Connect No.* needs to include the IP address of the target DNP device*.
- when the *Destination Port* is a Hayes Modem port, the *Connect No.* field needs to include the PSTN or GSM phone number.

*The *Connect No.* for IP Static routes will be updated when a DNP message is received from the target DNP device. The updated *Connect No.* will include the IP address, IP transport (TCP or UDP), and the IP port number.

**TIP: If a fixed IP address and port number is required, use a FIXED route (see *Fixed Routing* below).**

### Fixed Routing

FIXED routes are similar to STATIC routes except that the *Connect No.* field is **not** updated by the RTU. FIXED routes can have either an OFFLINE or ONLINE status, though are considered ONLINE when the

RTU is determining whether or not to add a DYNAMIC route entry (see Section ***Dynamic Routing & Routing Rules (Dynamic Routing)*** 74), i.e. if the status of a route entry is OFF FIXED, a DYNAMIC route entry will **not** be added to the DNP Route table.

## 7.2 Dynamic Routing & Routing Rules

### Dynamic Routing

The following fields are updated by the RTU network layer for maintaining DYNAMIC route entries:

*Status:* The status & type of the route entry. The status may have the following values:

**Online**: This route entry is being serviced
**Offline**: This route entry is not being serviced

The type of route entry may be one of:

**Static**: This route entry was manually entered
**Dynamic**: This route entry was automatically entered & has a lifetime before being put offline

*Lifetime:* The remaining time (in seconds) for an online dynamic route to be put offline. Each time a packet is routed using this entry the lifetime field is reset. The default lifetime for a dynamic route entry is 300 secs (5 mins).

The SCADAPack E RTU network layer automatically creates dynamic route entries under certain circumstances. For example, if an outbound packet is routed to a known RTU, but no static route entry exists for the return route path then the RTU's network layer creates an online dynamic route entry for the return route path. Without this entry the RTU would not normally be able to route the reply back to the sender. This mechanism is used to route mobile DNP addresses, such as PC based configuration & diagnostic packages.

Automatic route entry creation will also be used where return route entries for standard static routing are not configured by the user. It is suggested that return routes are statically entered by the user. Static routes are processed more efficiently by the SCADAPack E RTU than dynamic routes.

Dynamic route entries are added to the bottom of the route table. New dynamic entries replace older offline dynamic entries.

A DYNAMIC route entry will **not** be added to the DNP Route table, if the status of an existing relevant route entry is OFF FIXED.

### Routing Rules

Where multiple route entries exist which may potentially route the same data link packet, the order of priority in processing the route table is as follows:

1. Route entries are processed in order from top of route table to bottom
2. Route entries with OFFLINE status are skipped in the processing order
3. Entries are processed in order regardless of Static or Dynamic status

To improve routing efficiency and simplify network configurations, Source Address ranges should be as generalized as possible. Destination Address ranges should target specific sub-network groups.

Received DNP frames are routed according to the following rules:

1. If received frame matches this RTU's DNP address, the frame is processed.
2. If frame is a broadcast (65535), it is processed locally.
3. Route table is searched for matching source address, source port and destination address. If a matching route entry is found, frame is forwarded to the destination port.
4. If a frame is received on a local RTU port that is not the designated Master" port, and the route

table is empty, the frame is forwarded to the “Master” port.

5. If the above rules are not met, frame is discarded.

## 7.3 DNP3 TCP/IP Networking

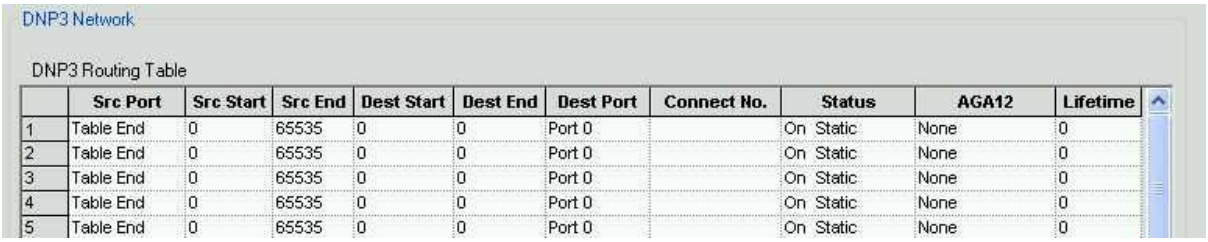
This section details specific TCP/IP conditions with respect to DNP3 Network Forwarding and Advanced DNP3 TCP/IP Networking.

### DNP3 Network Forwarding with TCP/IP

When configuring the network forwarding facilities of the SCADAPack E RTU and where serial ports are set for PPP-TCP/IP transport rather than DNP3, *treat the forwarding of DNP3 packets as if every port were set to DNP3* on a standard RTU DNP3 RTU. Similarly, where an RTU Ethernet interface is used for DNP3 communication, treat the port as another DNP3 protocol port. Each PPP-TCP/IP serial port and the RTU Ethernet port provides a virtual DNP3 connection (both UDP and TCP sockets are active). The PPP-TCP/IP and Ethernet interface transport of DNP3 frames is transparent to the DNP3 operation of the RTU. I.e. DNP3 frame forwarding operates in the same way for PPP-TCP/IP serial ports and the Ethernet interface as for conventional DNP3 serial ports.

Recall, the DNP Node Routing Table configuration describes how DNP3 frames are forwarded between communication channels, and which frames a particular device should forward. IP information is added to the routing table using the *Connect No.* field. Other than this field, the operation of other route entry fields is the same as in a DNP3 only system. For more information see Section ***DNP3 Networking*** 70.

It is recommended that RTU DNP Node number "0" not be used in remote RTUs as this is the default, un-configured RTU DNP3 Node address. Use DNP3 node addresses in the range 1-65519.


DNP3 Network

DNP3 Routing Table

| | Src Port | Src Start | Src End | Dest Start | Dest End | Dest Port | Connect No. | Status | AGA12 | Lifetime |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Table End | 0 | 65535 | 0 | 0 | Port 0 | | On Static | None | 0 |
| 2 | Table End | 0 | 65535 | 0 | 0 | Port 0 | | On Static | None | 0 |
| 3 | Table End | 0 | 65535 | 0 | 0 | Port 0 | | On Static | None | 0 |
| 4 | Table End | 0 | 65535 | 0 | 0 | Port 0 | | On Static | None | 0 |
| 5 | Table End | 0 | 65535 | 0 | 0 | Port 0 | | On Static | None | 0 |

**Figure 8.1: DNP Network Routing Table**

#### Connect Number

Null terminated string, Maximum 25 characters. Default value = Null.
Represents connection number relevant to destination port.

When routing using DNP3 over IP networks, valid IP Address Formats for "Connect No." field are:

| | | |
|---|---|---|
| *nnn.nnn.nnn.nnn* | IP address only*1: | e.g. 192.168.0.249 |
| *nnn.nnn.nnn.nnn*:T | use TCP transport*2 | e.g. 192.168.0.249:T |
| *nnn.nnn.nnn.nnn*:U | use UDP transport*2 | e.g. 192.168.0.249:U |
| *nnn.nnn.nnn.nnn*: pppppU | use UDP port number | e.g. 192.168.0.249:7001U |

*1 uses default transport and port number – see Section ***DNP3 Operation Using TCP/IP** 64.
*2 uses default port number – see Section ***DNP3 - TCP Keep-Alive Timer** 67 **(Default DNP3 Port)** 67.

The SCADAPack E RTU DNP Network Routing Table is organized in rows. Each row contains one route table entry and describes one scenario for routing of DNP frames received at this node.

Due to the connection oriented nature of TCP transport, specifying a TCP port number on an individual "Connect No." field string is not supported.

RTU routing table parameters may be adjusted dynamically via the SCADAPack E Configurator, or manipulated by an RTU ISaGRAF application ***Changes take effect immediately.***

Entries may be automatically added to this table by the RTU if a received IP packet is destined for a known DNP address, but where the return path for a response is via an unknown IP address. Such entries are known as DYNAMIC route entries and are used when roaming DNP addresses communicate with static DNP addresses (such as a laptop accessing remote RTUs). While this mechanism can be used to automatically determine return path communications for responses to request who have a configured forward path entry, it is recommended that known static return path entries be configured by the user.

The routing table *STATUS* field will contain one of the following values:

Static / Online - User entry
Static / Offline - User entry currently inactive
Fixed / Online - User entry (connect no. not updated by RTU – see Section ***Static & Fixed Routing*** 72 **[Fixed Routing]** 72)
Fixed / Offline - User entry currently inactive (onnect no. not updated by RTU – see Section ***Static & Fixed Routing*** 72 **[Fixed Routing]** 72)
Dynam / Online - Automatically created entry
Dynam / Offline - Automatically created entry with expired lifetime

## Advanced DNP3 TCP/IP Networking

Additional networking features such as tracking IP & UDP/TCP information for multiple hosts is provided by the RTU.

For more information on these and other advanced techniques for networking the RTU TCP/IP and/or DNP3 see the *SCADAPack E TCP/IP Technical Reference* manual.

## 7.4 STATUS ASSOCIATIONS

The **STATUS** command supports additional optional parameters for DNP3 IP associations tracking. ( **ASSOCIATION**).

- Maximum number of associations. This will be normally be one hundred.

The following information is displayed for each association:

- Association type (local, paired routing or solitary routing)
- Local or Source DNP3 address (a valid DNP3 address. Local address will be the RTUs local DNP3 address)
- Remote or Destination DNP3 address (a valid DNP3 address)
- *Remote or Destination IP address (a valid IP address)*
- IP connection type (TCP or UDP)
- Socket or port number (The TCP socket number will vary depending on the current connection. UDP port number will typically be 20000)
- Time since last activity on the association (hours:minutes:seconds)
- The current state of the association (ACTIVE, PAIR PENDING, INACTIVE, NO SOCKET)

**NOTE**: Further information about DNP3 IP Associations can be found in *Annex "C"*, *IEEE Standard for Electric Power Systems Communications - Distributed Network Protocol (DNP3), IEEE STD 1815™-2012*.

This information is presented in addition to the standard status information and an example is shown as follows. Note that the local DNP3 address in the example is 20:

```
C:\>status association
RTU Uptime:          0 days, 00:53:04

ISaGRAF Target 1: Stopped
ISaGRAF Target 2: Stopped

Reset Counter:       2
Reset Reason mask:   0x000E
Task Watchdog mask:  0x0000
Sys Last Error:      0
Sys Memory Free:     127696196 bytes
Sys Memory Size:     129049772 bytes

DNP IP Associations:
Limit of 100 associations
```

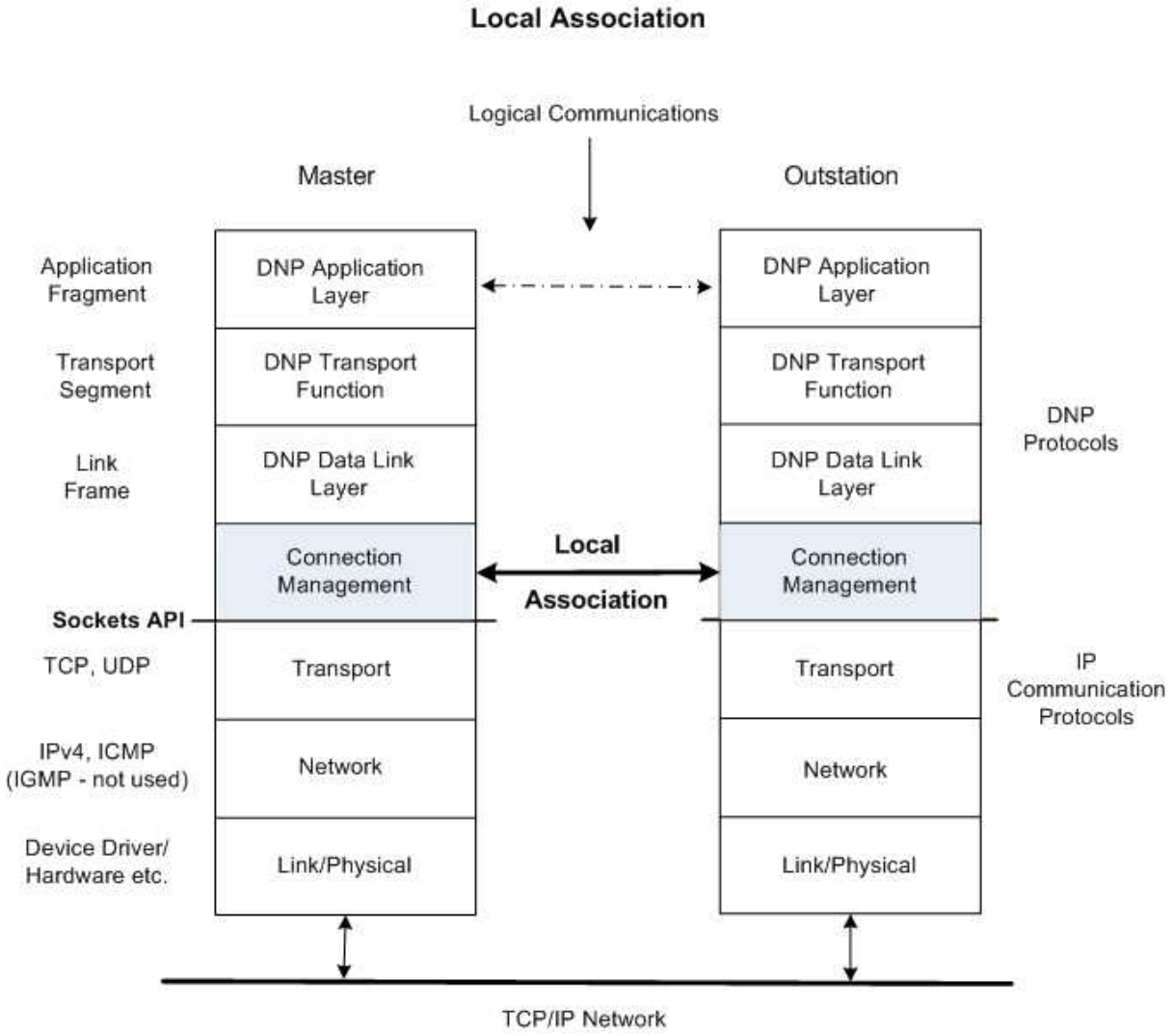
## ASSOCIATION TYPES

### Local Associations

Local Associations are associations between two nodes where one of the nodes is the local RTU. If the

RTU has multi-master functionality enabled and configured, then the 'local' RTU is any of the configured DNP3 slaves.

The Protocol Stack communications and connection management configuration for Local Associations is shown in the figure, below:




The status information for Local Associations is presented below:

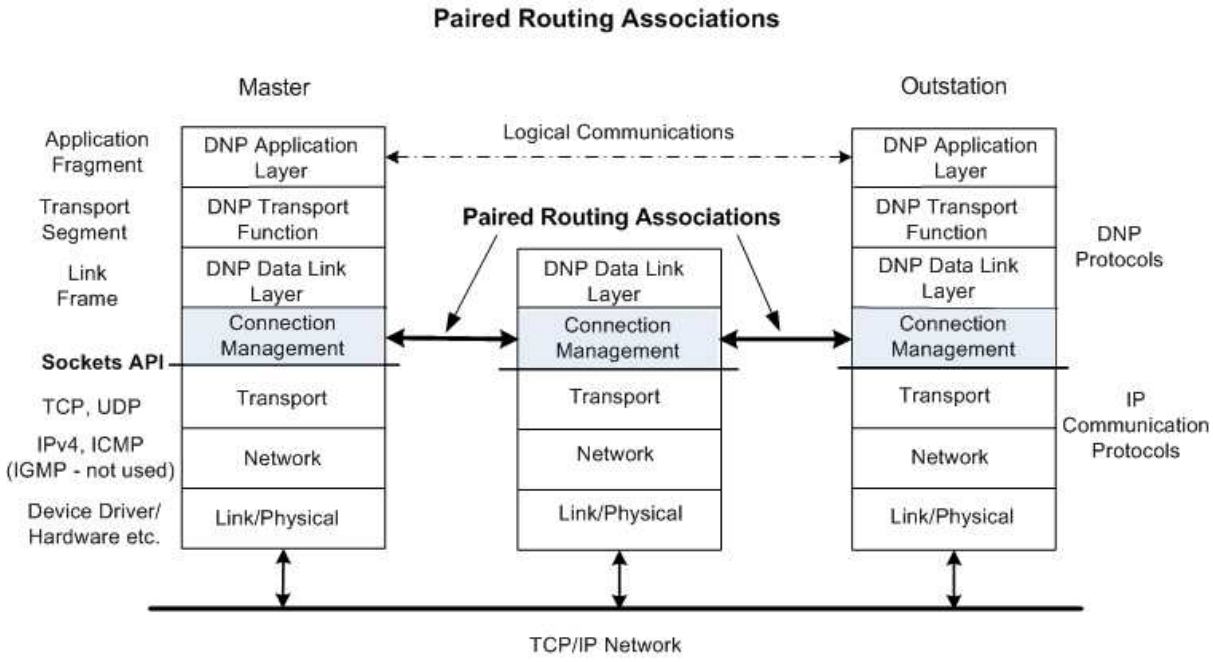
```
Local Associations

Local | Remote| Remote IP       | TCP/ | Sock/ | Time     | State       |
DNP   | DNP   | address         | UDP  | Port  | since    |             |
addr  | addr  |                 | Type | Num   | last msg |             |
-------------------------------------------------------------------------
   20<->32111 | 172. 20.  1.165 | TCP  | -1    |  0:52:16 | INACTIVE    |
   20<->2000  | 172. 20.  1.165 | TCP  | 146   |  0:09:46 | ACTIVE      |
```

## Paired Routing Associations

Paired Routing Associations are routing associations between two other nodes, neither of which are the local RTU. The local RTU performs DNP3 routing on behalf of the other RTUs. There are two associations; one for each transmission direction between the other two RTUs.

The Protocol Stack communications and connection management configuration for Paired Routing Associations is shown in the figure, below:




The status information for Paired Routing Associations is presented below:

```
Paired Routing Associations
Source| Dest   | Remote IP       | TCP/ | Sock/ | Time     | State       |
DNP   | DNP    | address         | UDP  | Port  | since    |             |
addr  | addr   |                 | Type | Num   | last msg |             |
-------------------------------------------------------------------------
  100-->1300  | 172. 16. 29. 75 | UDP  | 20000 |  0:02:16 | ACTIVE      |
 1300-->100   | 172. 20.  1.165 | TCP  | -1    |  0:02:16 | INACTIVE    |
  800-->1600  | 172. 16. 29. 55 | TCP  | 0     |  0:01:41 | NO SOCKET   |
 1600-->800   | 172. 20.  1.165 | TCP  | 142   |  0:01:41 | ACTIVE      |
```

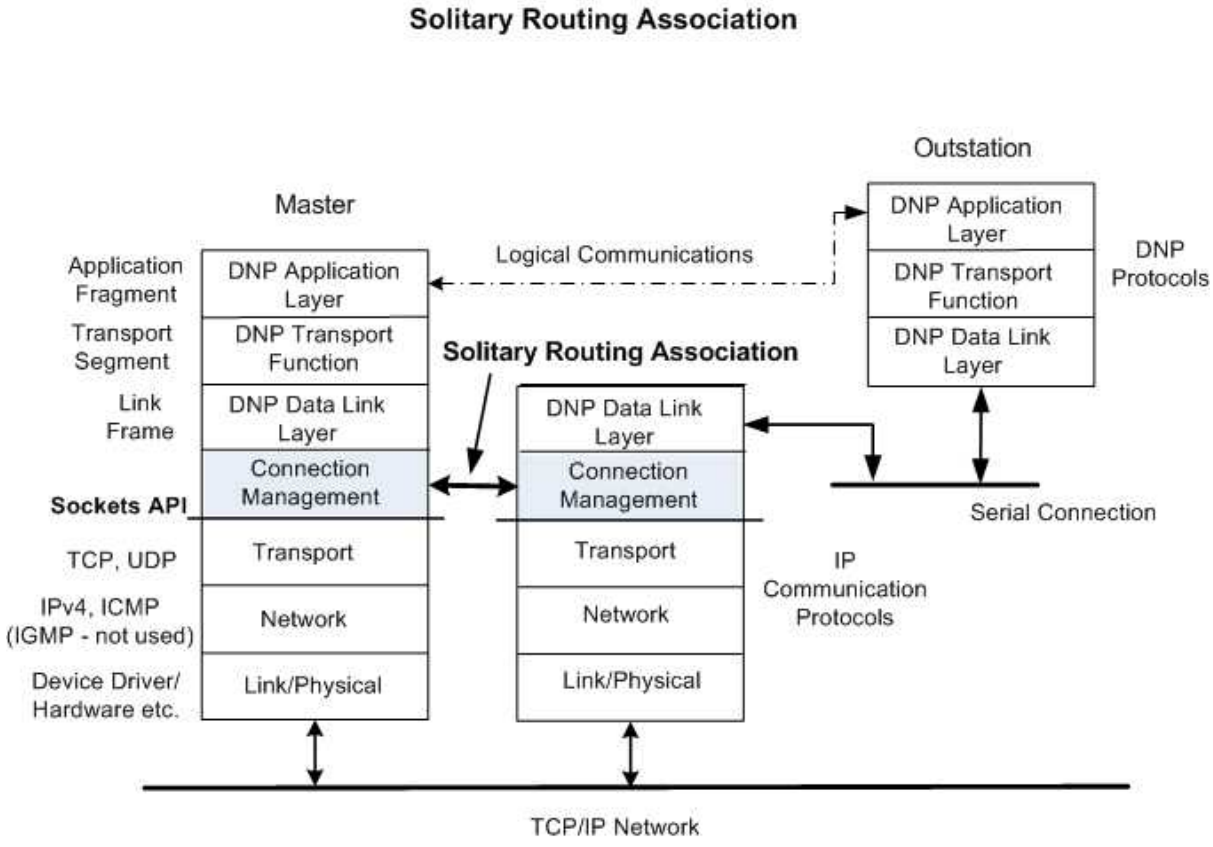
## Solitary Routing Associations

Solitary Routing

Solitary Routing Associations are similar to Paired Routing Associations. Solitary Routing Associations apply to a single pair of nodes that are not the local RTU; one node in the pair is connected serially, and the other node is connected over IP. The Solitary Routing Association stores the information that is

required to communicate with the RTU connected over IP. Association for the serially connected node is not necessary; the required information is currently stored in the DNP3 Route table.

The Protocol Stack communications and connection management configuration for Solitary Routing Associations is shown in the figure, below:




The status information for Solitary Routing Associations is presented below:

```
Solitary Routing Associations

Source| Dest   | Remote IP       | TCP/ | Sock/ | Time     | State       |
DNP   | DNP    | address         | UDP  | Port  | since    |             |
addr  | addr   |                 | Type | Num   | last msg |             |
-------------------------------------------------------------------------
  750-->1800   | 172. 16. 29. 55 | TCP  | 148   |  0:00:04 | ACTIVE      |
  375-->1252   | 172. 16. 29. 75 | UDP  | 20000 |  0:00:07 | ACTIVE      |

Security:
DNP3 Secure Authentication: Not configured
AGA12 Encryption for DNP3:  Not configured
Master Key:                 Not set

C:\>
```

## Related Topics

ASSOCIATION STATES 82

### 7.4.1 ASSOCIATION STATES

There are a number of Association States that apply to these Association Types:

- Local Associations
- Paired Routing Associations
- Solitary Routing Associations

## Association States

The Association States are listed below:

### Active

The association is complete and fully operational.

### Pair Pending

This state is valid for paired routing associations, only. The first association of a pair of routing associations is set to Pair Pending when the second association has not been set up correctly. After the second association has been set up correctly, the pair pending association changes to an "active" state.

### Inactive

The association has become inactive; typically as a result of the socket being closed. New outgoing traffic requiring this association, can usually trigger the negotiation of a new socket. This action moves the association to the "no socket state". Incoming traffic must establish a new socket before being received and this moves the association to the "active" state.

### No Socket

The association has been set up, but is waiting for the TCP/IP stack to successfully negotiate with the other device to establish a socket. After the socket has been established, the socket moves to the "active" state.

DNP3 associations are applicable to both Ethernet and PPP connections. During variable connection states, that is, when a connection is active/inactive over a keep-alive time interval, DNP3 TCP keep-alive messages are sent only when a TCP connection over IP or PPP is involved.

The DNP3 TCP keep-alive messages are issued on active DNP3 channels according to the configured keep-alive interval. Typically, there is a one-to-one correspondence between a DNP3 channel and a DNP3 association.

Under certain circumstances, in addition to these regular keep-alive messages, an association that is experiencing communication difficulties also triggers the transmission of a DNP3 keep-alive message. When a DNP3 keep-alive message fails, it triggers the closure of an RTU DNP3 channel and this in turn

prompts the deactivation of any associations using that channel.

### Related Topics

STATUS ASSOCIATION 78

# 8 SCADAPack E DNP3 Driver Status Codes

The following status codes may appear in RTU Diagnostics (particularly DNP3 driver diagnostic output). They may also appear in ISaGRAF Peer Function Block return status:

**SCADAPack E DNP Driver Status Codes** (dec)

1 - Success
2 - Function Code not supported in response fragment
3 - Sequence number in response fragment did not match recent request frag
4 - Response fragment received with no active request
5 - Object/Variation not supported
6 - Object/Qualifier combination not supported
7 - Qualifier code in response fragment not supported
8 - Timeout waiting for application layer response fragment or restart
9 - Object Variation not supported in read response fragment
10 - Object Variation not supported in operate response fragment
11 - Internal Indication (IIN) bits set relating to remote device parsing of last request
12 - Response fragment to “select before operate” does not match request fragment
13 - Response to restart message does not contain time object
14 - Object Variation not supported in write response fragment
15 - Data for application layer transmit queue contains invalid device index
16 - Response to delay measurement message does not contain time object
17 - Unsolicited Responses disabled, data in message not processed
18 - Invalid DNP point index
19 - Requested DNP data caused buffer overflow in application fragment
100 - Application Layer Confirm received with no matching response sequence number
111 - Timeout waiting for Application Layer Confirm to Read Response
112 - Timeout waiting for Application Layer Confirm to Unsolicited Response
113 - Aborted Multi-fragment Response (timeout on expected Confirm)
123 - Virtual Terminal object data invalid
124 - Request rejected due to insufficient user permissions
125 - File transfer failed
126 - DNP driver not ready, request not sent
127 - Could not transmit application request
128 - Memory has been freed due to a Warm Reset of the DNP driver
252 - Invalid DNP function code in ISaGRAF Function Block
253 - Invalid DNP point index in ISaGRAF Function Block
254 - Invalid DNP object in ISaGRAF Function Block
255 - Outstanding request in progress (waiting for response or timeout)

**RTU DNP3 IIN errors (returned by remote device)**

50 - Bad function, not implemented
51 - Requested object unknown
52 - Parameters are not valid or out of range

**RTU Control Block status errors (CROB or AO Block status)**

61 - Request not accepted as *operate* received after the arm timeout period
62 - No previous matching *select* message
63 - Request not accepted due to error in the control request
64 - Control operation not supported for this point
65 - Request not accepted as control queue filled or point already active
66 - Request not accepted due to control hardware problems

# 9 Common DNP3 Protocol Codes

The following codes appear in SCADAPack E DNP3 messages, and are provided as a quick reference guide.

**DNP3 Function Codes**

| (dec) | (hex) | |
|---|---|---|
| 0 | 00 | Confirm |
| 1 | 01 | Read |
| 2 | 02 | Write |
| 3 | 03 | Select |
| 4 | 04 | Operate |
| 5 | 05 | Direct Operate |
| 6 | 06 | Direct Operate no Acknowledge |
| 13 | 0D | Cold Restart |
| 14 | 0E | Warm Restart |
| 20 | 14 | Enable Unsolicited Messages |
| 21 | 15 | Disable Unsolicited Messages |
| 23 | 17 | Delay Measurement |
| 24 | 18 | Record Current Time |
| 25 | 19 | Open File |
| 26 | 1A | Close File |
| 27 | 1B | Delete File |
| 28 | 1C | Get File Information |
| 30 | 1E | Abort File |
| 32 | 20 | Authentication Request |
| 33 | 21 | Authentication Error |
| 129 | 81 | Response |
| 130 | 82 | Unsolicited Message |
| 131 | 83 | Authentication Response |

**DNP3 Qualifier Codes**

| (hex) | |
|---|---|
| 00 | 8 bit stop and start indices in the range field |
| 01 | 16 bit stop and start indices in the range field |
| 06 | all objects of given type (no range field) |
| 07 | 8 bit single field quantity |
| 08 | 16 bit single field quantity |
| 17 | 8 bit quantity of 8 bit indexes list |
| 28 | 16 bit quantity of 16 bit indexes list |
| 1B | 8 bit quantity of 8-bit no. of free format object headers (used in g70v1 legacy file object) |
| 5B | 8 bit quantity of 16-bit length free format object headers |

**DNP3 Control Relay Output Block (CROB) Codes**

(hex)

| | |
|---|---|
| 01 | Pulse On |
| 02 | Pulse Off |
| 03 | Latch On |
| 04 | Latch Off |
| 41 | Trip (Pulse On)} Trip & Close is used with different DNP point numbers |
| 81 | Close (Pulse } as per DNP Control Relay Output Block Minimum Implementation On) |

**DNP3 Control Object Status**

Control Object Status code values appear in DNP3 responses in the status byte of the following control objects:

Group 12 Variation 1 - Control Relay Output Block (CROB)
Group 13 Variation 1 - Binary Output Command Event without Time
Group 13 Variation 2 - Binary Output Command Event with Time
Group 41 Variation 1 - 32-bit Analog Output Block
Group 41 Variation 2 - 16-bit Analog Output Block
Group 41 Variation 3 - Short Floating Point Analog Output Block
Group 43 Variation 1 - Analog Output Command Event - 32-bit without Time
Group 43 Variation 2 - Analog Output Command Event - 16-bit without Time
Group 43 Variation 3 - Analog Output Command Event - 32-bit with Time
Group 43 Variation 4 - Analog Output Command Event - 16-bit with Time
Group 43 Variation 5 - Analog Output Command Event - Single precision floating point without Time
Group 43 Variation 7 - Analog Output Command Event - Single precision floating point with Time

Status:
- **0** Request accepted, initiated or queued
- **1** Request not accepted as *Select Arm Timeout* has expired
- **2** Request not accepted as no previous matching *Select* was Received to this *Operate*
- **3** Request not accepted as there were formatting errors in control request
- **4** Control operation not supported for this point
- **5** Request not accepted, as point is already active (e.g. attempting to control output point when an ISaGRAF application has control of the point)
- **6** Request not accepted because of control hardware
- **7** Request not accepted because Local/Remote switch is in Local position
- **8** Request not accepted because too many objects appeared in the same request
- **9** Request not accepted because of insufficient authorization
- **10** Request not accepted because it was stopped by a local automation process
- **11** Request not accepted because the device cannot process any more activities than are presently in progress
- **12** Request not accepted because the value is outside the acceptable range for this point
- **13-127** Undefined